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Computer Integrated Manufacturing (CIM) is the coordinated application of technology to the process of design manufacturing, distribution, and maintenance for a product or group of products. The approach taken to perform the study was to logically group and define CIM technologies as a foundation for further analysis and as a basis for defining high-payback strategies for future Army CIM efforts. The next step was to assess the current state of Army efforts in CIM development and implementation. This was accomplished by researching industry and government manufacturing technology data bases and (Cont.)

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interviewing knowledgeable individuals within the Army Materiel Command. After relevant programs and projects were identified, the current strategies were analyzed and compared to those of other government agencies, private commercial organizations and universities. Finally, alternate strategies were identified along with related risks and benefits.

An Analysis of
Computer Integrated Manufacturing (CIM)
Technology, Benefits and Strategies
for the
U.S. Army Materiel Command

(Contract No. DAAA08-86-M-8578 dated 15SEP86)

by

Arthur Andersen & Co.

December 1986

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1. Introduction

The purpose of this briefing is to analyze the U.S. Army's strategy regarding the promotion, acquisition, development and utilization of Computer Integrated Manufacturing (CIM) technologies. The study was performed by representatives of Arthur Andersen and Co. in response to requests for information from the Department of the Army and the Army Materiel Command. Contractor efforts were supervised by the Industrial Base Engineering Activity located in Rock Island, Illinois, under contract order number DAAA08-86-M-8578.

Project team personnel for Arthur Andersen & Co. were Roger G. Willis (partner), John P. Piatt (consulting manager) and Steven R. Dimitriyev (staff consultant). Stephen McGlone and James Carstens from the Industrial Base Engineering Activity supervised project efforts, provided information resources and facilitated personal interviews.

The scope of the study was by no means an exhaustive survey and analysis of all U.S. Army activities. It had substantial time and funding constraints, and therefore had to be limited to a high-level review of representative activities and organizations within the AMC.

The approach taken to perform the study was to logically group and define CIM technologies as a foundation for further analysis and as a basis for defining high-payback strategies for future U.S. Army CIM efforts. The next step was to assess the current state of U.S. Army efforts in CIM technology development and implementation. This was accomplished by researching industry and government manufacturing technology data bases and interviewing knowledgeable individuals within the AMC. After relevant programs and

projects were identified, the current strategies were analyzed and compared to those of other government agencies, private commercial organizations and universities. Finally, alternate strategies were identified along with related risks and benefits. A recommendation for the AMC's role in a U.S. Army CIM strategy was identified along with a potential action plan.

2. Executive Summary

The purpose of this briefing is to analyze the U.S. Army's strategy regarding the promotion, acquisition, development and implementation of Computer Integrated Manufacturing. Computer Integrated Manufacturing (CIM) is the coordinated application of technology to the process of design, manufacturing, distribution and maintenance for a product or group of products. The primary objectives of CIM are to improve service to customers, increase flexibility, boost productivity, enhance product quality and sustain profitable operations.

The basic engineering and manufacturing functions of CIM focus on four major themes as defined by the Computer and Automated Systems Association of the Society of Manufacturing Engineers:

1. Factory Automation which encompasses activities such as computer numerical control, flexible manufacturing systems, robots and automated material handling systems
2. Product and Process Definition which concentrates on concepts such as group technology, Computer Aided Design (CAD), Computer Aided Engineering (CAE) and artificial intelligence
3. Manufacturing Planning and Control which focuses on processes such as material requirements planning, purchasing, materials management and Just-In-Time (JIT) techniques
4. Integrated Systems Support Architecture which is composed of hardware, software, communication and integration elements

The specific technologies that support these functional disciplines are as follows:

I. Factory Automation

1. AMH - Automated Material Handling
2. Factory Communications
3. CAI - Computer Aided Inspection
4. FAS/FMS - Flexible Assembly and Manufacturing Systems

5. Advanced Data Collection Technologies
6. Process Control

II. Product/Process Engineering

1. CAD - Computer Aided Design
2. CAE - Computer Aided Engineering
3. GT - Group Technology
4. AI - Artificial Intelligence
5. CAM - Computer Aided Manufacturing
6. TDP (Technical Data Package) Management

III. Manufacturing Planning/Control

1. MRP II - Manufacturing Resource Planning
2. JIT - Just-In-Time Techniques
3. Statistical Process Control (SPC)
4. Simulation
5. Maintenance Management
6. Quality Management

IV. Integrated Systems Support Architecture

1. Hardware
2. Software
3. Integration
4. Communications

AMC efforts in CIM were determined by interviewing 17 individuals who represented the following organizations:

- o AMC/HQ
- o Information Management Directorate
- o LABCOM
- o CECOM
- o AMCCOM
- o DESCOM
- o ARDEC
- o AMETA
- o IBEA

Additional information was gathered using electronic data bases and searches of current literature. These surveys identified 42 CIM study phase projects currently planned or in process by AMC organizations.

The 42 projects have the following concentrations in specific technologies (note that total of concentrations will be greater than total of projects).

FACTORY AUTOMATION

o AMH	4
o Factory Communications	3
o CAI	8
o FAS/FMS	8
o Advanced Data Collection	2

PRODUCT/PROCESS ENGINEERING

o CAD	7
o CAE	2
o GT	3
o AI	4
o CAM	18
o TDP Management	3

MANUFACTURING PLANNING/CONTROL

o MRP II	5
o JIT	0
o SPC	6
o Simulation	3
o Maintenance Management	4
o Quality Management	7

INFORMATION PROCESSING SUPPORT

o Hardware	5
o Software	9
o Integration	3
o Communication	5

The only major concentration noted was a slight emphasis on Computer Aided Manufacturing (CAM-NC, CNC and DNC). One notable weakness is the absence of any project dealing with JIT (Just-In-Time) manufacturing simplification techniques. This is particularly bothersome since these techniques have been proven to produce substantial short- and long-term benefits in

work-in-process inventory, manufacturing lead time, manufacturing space requirements and equipment utilization. The major programs planned that were not listed are as follows:

- o CALS (Computer-Aided Logistics Support) - A system to be installed at a number of U.S. Army sites worldwide. It will provide a mechanism for capturing, maintaining and providing access to technical information generated during the Army material acquisition process. This program has commenced but the majority of efforts will extend well into the 1990s. The U.S. Navy and U.S. Air Force have similar CALS initiatives, within the DoD CALS initiative.

- o DSREDS/EDCARS (Digital Storage and Retrieval of Engineering Data System) - A joint U.S Army/U.S. Air Force effort to capture paper-based technical data and convert it to digital format in electronic media. Currently in progress with the first site due to come online at MICOM in Huntsville, Alabama.

- o Army Corps of Engineers CAD Acquisition - A $120 million acquisition for the purchase of computer-aided design hardware and software to support Corps of Engineers' sites in the U.S. and overseas.

A number of other organizations were surveyed to determine their approach to implementing CIM. The three major types of organizations surveyed are:

1. Government agencies
2. Commercial enterprises
3. Educational institutions

The other government agencies were the:

- o U.S. Navy
- o U.S. Air Force
- o Department of Energy
- o NASA
- o Veterans Administration

The major focus of their efforts is:

- o Centralized control of CIM efforts
- o A strategic emphasis for CIM in management plans

- Joint ventures with other organizations when developing or implementing a CIM technology

The commercial enterprises surveyed were:

- Allen-Bradley
- AT&T
- Chrysler
- Deere & Co.
- Ex-Cell-O Corporation
- General Electric
- General Motors
- IBM

The major focus of their efforts is:

- Use of CIM technology as a tool for competitive advantage
- Simplifying manufacturing operations before installing automation
- A major commitment to data and communication integration standards
- High-level management support of CIM, usually through the creation of a vice president level position to manage CIM technology implementation

The educational institutions surveyed were:

- Arizona State
- Brigham Young
- Georgia Tech
- Lehigh
- Michigan
- Ohio State
- Purdue
- Tulane

The major focus of their efforts is:

- Many cooperative programs with commercial enterprises
- A shortage of CIM funding and qualified instructors
- A primary direction of research concerning new technology and developing applications of existing technology
- A high demand for CIM graduates

As a result of analyzing the information obtained in the data collection phase, a number of strengths and weaknesses were discovered for the current strategy. While the strengths and weaknesses are discussed in greater detail in the Analysis section, they are summarized as follows:

Strengths

1. A substantial pool of personnel who are dedicated and knowledgeable in CIM technologies
2. A positive perception of CIM benefits by operational-level personnel
3. The DCS for Production has provided an initial focus for CIM within AMC
4. Substantial progress has been made in a number of stand-alone CIM implementations
5. Organizations are in place that provide various resources to AMC personnel who are implementing CIM
6. AMC management and operational-level personnel are aware that problems exist with current AMC efforts in CIM
7. Several projects (CALS, DSREDS/EDCARS, NBS/AMRF) that promote joint-service cooperation in CIM technology have been initiated

Weaknesses

1. Lack of an officially-defined strategy for promoting and implementing CIM
2. Lack of a single focal point for CIM information and guidance
3. CIM efforts are designed to solve local problems without regard to AMC-wide benefits
4. A focus on developing "hard" manufacturing technologies as opposed to being a definer and manager of manufacturing data in electronic format
5. A lack of adequate support for popular data integration standards
6. An absence of a CIM planning and implementation methodology to ensure efficient expenditure of resources
7. Numerous and complex regulations and procedures that block efficient CIM implementation efforts
8. An apparent high turnover ratio for skilled CIM practitioners within AMC

9. Current efforts do not encourage an effective level of CIM investment by AMC contractors

10. Existing educational resources, while available, are not fully utilized by management personnel at local AMC facilities

Since the current strategy does not effectively address these problems, the AMC should look towards developing and implementing a strategy that will focus on eliminating these weaknesses.

Many different alternatives present themselves as options to the current strategy. In order to evaluate different alternatives, several evaluation criteria were developed.

The evaluation criteria are divided into two categories--primary and secondary. The primary criteria have a higher priority because they relate directly to the primary mission of the Army Materiel Command. The primary criteria are defined as follows:

- Reduce Acquisition Costs - Strategies are rated according to how well they will reduce weapon system acquisition costs--both long-term and short-term.
- Reduce Operating Cost - The ability to reduce operating cost and enhance maintainability will be a primary concern in rating any strategy.
- Improve Product Quality - The reliability of any weapon system is a critical factor in determining whether a strategy will be implemented.
- Improve Production Throughput - Any increases in productivity achieved as a result of implementing a strategy will make that strategy more attractive.

Secondary criteria as a group, while still very important, carry somewhat less weight than the primary criteria. Those criteria are defined as follows:

- o Increase Intangible Benefits - The ability to attract and retain talented personnel with CIM skills is an example of a valuable intangible benefit.

- o Implementation Cost - The implementation cost for any new strategy might be prohibitive to the extent that initial phase funding would not be available.

- o Implementation Risk - If a strategy fails during the implementation phase, it could have far-reaching adverse impacts. Management support for future endeavors could evaporate and the confidence and morale of the implementation team could be damaged.

There are a number of strategies that the AMC might pursue to promote CIM. Each of these strategies would be composed of different elements. Some elements may be used in a number of different strategies. The following strategic elements will be included in the alternate strategies that are presented for review.

a. Establish an Official CIM Advocate at AMC/HQ - The creation of a single person or group as a focused source of guidance in all matters relating to CIM is essential.

b. Create a CIM Information Sharing Mechanism - The ability to share information concerning progress made in the diverse and rapidly changing field of CIM is crucial.

c. Enhance CIM Education Programs - Mandating structured training programs for different levels of personnel within AMC will improve management support, eliminate resistance based on inaccurate beliefs and increase the efficiency of CIM planners, designers and implementors.

d. Develop and Communicate a CIM Goal - A statement of purpose and associated guidelines for future action in the CIM field are required for efficient application of future efforts. AMC personnel will have more confidence and less frustration if they feel that their work is resulting in substantial progress towards a realizable goal.

e. Attract and Retain Personnel with CIM Skills - More AMC effort is needed to attract and retain personnel with valuable CIM skills. Enhancing the current CIM skill base will, in itself, create a substantial momentum towards the achievement of an enhanced CIM capability.

f. Develop a Methodology for CIM Implementation - An effective methodology for planning, designing and implementing CIM technology will ensure that all efforts are applied in a consistent and logical manner.

g. Establish Policies and Procedures that Enhance the Implementation of CIM - Any overly complex or restrictive policies or procedures relating to the implementation of CIM should be relaxed in favor of guidance from a central CIM advocate and a general CIM goal.

h. Develop Alternate CIM Capital Expenditure Justification Techniques - CIM efforts within the AMC and government contractor organizations would be facilitated by providing alternate capital expenditure justification techniques.

i. Engage in Joint Acquisitions with Other Government Agencies for Similar CIM Technologies - The economies of scale that can be realized by sharing acquisitions of similar technologies can be very beneficial.

j. Sponsor Research of CIM Technology at Educational Institutions and Research Organizations - Providing financial and personnel support to a number of research-oriented activities would be a method for "getting the jump on" emerging technologies. The AMC would be seen as being on the leading edge of CIM technology innovation, and the resultant publicity would provide some justification for future efforts.

k. Mandate Certain CIM Technologies in Acquisitions of Major Weapons Systems - An effective means of persuading contractors to produce products and related technical documentation in an efficient manner is to include requirements for CIM in an RFP.

l. Provide Support to Existing de Facto and Semi-Standards for Data Communication - The AMC should analyze the standards to determine which of them provides the most functionality or has the greatest popularity. Then, it should provide support in the area of funding, furnishing personnel to assist in research and promoting the use of the standard in weapons system acquisitions.

m. Allow any AMC Facility to Purchase CIM Technology within High-Level Budget Guidelines - Any AMC facility should be allowed to purchase CIM technology to fill its specific needs. The flexibility gained would allow for a rapid infusion of CIM technology into the AMC.

n. Create CIM Technology Guidance Organizations to Serve Specific Functional and Geographical Needs - A variety of organizations offering technical and funding assistance to specifically defined entities within AMC would promote CIM within their own spheres of influence.

Now that the number of strategic elements have been defined, we can proceed to developing and analyzing overall CIM strategies. The criteria mentioned previously were used to rate the strategies.

The strategies selected are discussed and ranked as follows:

1. Current Strategy - This strategy is characterized by a number of ongoing CIM projects being managed by many different organizations within AMC. A variety of groups (DCS for Production, IBEA, AMSRC, LSRC, CAD/CAM Steering Group) are giving guidance in CIM technology. Funding is shared by a number of different programs (MMT, AIF, Army Civil Works) and relatively small portions (2%) of weapon system acquisition funding is used to promote CIM technology.

   Strategic Elements: k, m, n

   Criteria Evaluation Points: 29

2. Promote Digitization of Data within AMC - This strategy is characterized by a focus of reducing paper-based information used to acquire, operate and maintain weapon and support systems used by the U.S. Army. Instead, all information would be converted to an electronic digital format that will produce benefits in the areas of space requirements, data accuracy, data access time and data analysis. This strategy will be composed of elements that will promote the production of new data in, and the conversion of existing data to, electronic digital format. A noteworthy point is that substantial progress has already been made in the area with the combined U.S. Army/U.S. Air Force DSREDS/EDCARS program.

   Strategic Elements: a, c, d, f, g, i, k

   Criteria Evaluation Points: 41

3. Incentivize Integration Technology within AMC - This strategy is characterized by active AMC support for various data integration standards. The objective would be to move many quasi or de facto standards into a widely accepted formal status. Key candidates would be IGES for graphic data exchange, PDES for product data exchange, MAP for a factory communication protocol, and TOP as an office and engineering environment communication protocol. The long-distance (packet switching) protocol X.25 has also gained wide acceptance. Substantial economic benefits will accrue due to equipment interoperability whenever a standard is widely accepted by a vendor and user community.

   Strategic Elements: a, c, d, e, f, g, k, l

   Criteria Evaluation Points: 47

4. Facilitate Contractor Investment in CIM - This strategy is characterized by providing a high level of support to contractors in their implementation of CIM technology. Current funding of CIM technology implementation at 2% of total acquisition costs appears to be somewhat low. In addition to increased funding, technical and educational assistance should also be provided. Subsequent phases of major acquisitions would accrue economic benefits due to the non-unique nature of many CIM technologies. Graphic and text data, as well as machining

instructions, could be developed by one contractor in a generic electronic format in the first phase, then distributed to a variety of contractors in subsequent phases.

Strategic Elements: a, d, f, i, h, k, l

Criteria Evaluation Points: 44

5. Create a CIM Technology Center - This strategy is characterized by the creation of an AMC-sponsored CIM technology research and education center. It would contain examples of the latest "state-of-the-market" manufacturing and systems technology. Personnel from the AMC, government contractors and educational institutions would staff and attend this center. Its main purpose would be to provide CIM education for AMC personnel and identify AMC as a leading proponent of CIM.

   Strategic Elements: a, c, d, e, j

   Criteria Evaluation Points: 32

On the basis of evaluation points, the highest rated strategy for the AMC would be Strategy 3, Incentivize Integration Technology within AMC. Two other strategies were also highly rated--Strategy 2, Promote Digitization of Data within AMC, and Strategy 4, Facilitate Contractor Investment in CIM. Since many of these strategies contain common elements, the action plan for AMC will initially encourage progress at the strategic-element level.

Arthur Andersen & Co. proposes a number of recommendations as an action plan to implement the strategies evaluated in the previous section. The basis for this action plan is that the highly evaluated strategies in the previous section contain several common elements and, thus, can be pursued independent of any specific strategy. The overall approach promoted by these recommendations is fairly straightforward:

1. Analyze the AMC's current status in terms of promoting and implementing CIM.
2. Determine where the AMC wants to be in terms of promoting and implementing CIM.
3. Choose the most efficient mechanism in going from point 1 to point 2.

The recommendations can be broken down into two different types--management and technical. The management action plan consists of the following specific recommendations, which should be implemented in sequential order:

1. Create a management position within AMC/HQ titled the AMC CIM Advocate. The mission of the advocate will be to efficiently coordinate CIM efforts in the AMC. The CIM Advocate should reside at AMC/HQ, but should travel extensively to AMC facilities to communicate an awareness of and support and guidance for CIM technology implementation. Authority for the CIM Advocate should reside at the AMC command level and it should be sufficient to allow for the fulfillment of its mission. Funding approval for all CIM-related efforts would be the most efficient method to exercise this authority. Although absolute funding approval is a desirable long-term goal, it might not be feasible to implement in the short term. A more appropriate short-term solution would be to mandate review of CIM funding requests by the CIM Advocate. An additional benefit is that the CIM Advocate would act as an information conduit for all organizations engaged in CIM activities with AMC. Also, it would serve as an easily identified CIM point of contact for organizations external to AMC. Current information flows follow a network model as illustrated in Figure 2. It is readily apparent that the current topology is not the most efficient mechanism for disseminating information. The proposed approach is illustrated in Figure 3. It employs the CIM Advocate as the hub of an "information wheel" with the spokes representing channels of information flow. This topology would provide for efficient CIM information capture and dissemination to all concerned organizations.

2. Develop and communicate an official CIM goal for the AMC. This goal is essential to ensure coordinated efforts among the many diverse and geographically isolated facilities that compose the Army Materiel Command. Current CIM efforts exhibit a tendency towards implementing solutions solely for the benefit of a specific facility, without regard to economies of scale that would benefit AMC as a whole. A properly composed and communicated goal would do much to improve coordination of individual efforts in CIM and would facilitate the efficient expenditure of limited CIM funds. An example of an appropriate CIM Goal is included in Exhibit 1. The guiding principles proposed are a variation of the three highest ranked strategies from the Criteria Evaluation Matrix and, as such, would provide a good foundation for the actual goal. The CIM Advocate should be tasked to develop the actual goal. After approval by AMC, DA and DoD management, it should be disseminated to all AMC personnel by a method consistent with its importance.

3. Plan for and take a detailed inventory of current CIM projects within the AMC. Data collected should include types of technology, funding

levels (expended and planned), funding sources, management programs, expected benefits (tangible and intangible), completion percent estimates, and involved personnel and their CIM skill descriptions. This task should be managed by an appropriate member of the CIM Advocate's staff. The method of data collection should be personal and telephone interviews combined with appropriate data base searches. Paper-based survey forms would not be an effective data collection technique.

4. Develop an overall strategy to obtain maximum benefit from CIM projects within total funding constraints. Wherever possible, efforts to develop similar technologies should be concentrated to avoid duplication of effort. Major emphasis should be given to cooperative efforts or joint ventures with other military services, government organizations, commercial enterprises, and research and educational institutions. Management programs and funding sources should be combined to eliminate confusion and enhance funding effectiveness. A prime example of where significant efficiencies could be achieved is the combination of the three independent efforts to install integrated manufacturing control systems at the Watervliet, Rock Island and Pine Bluff arsenals. Another high-potential area is the cross-fertilization of efforts between AMCCOM and DESCOM whenever a commonality exists. The inventory completed in step 3 will be a vital input to this process. The CIM Advocate should create a permanent staff group to perform this task. Staff group members should be selected on the basis of three factors:

   1. Knowledge of specific CIM technologies
   2. Functional expertise
   3. Command representation

   Once the overall strategy is developed, it should be implemented without delay.

In addition to the primary management recommendations, the AMC should pursue the certain technical recommendations. The following technical action points should also be supervised by the CIM Advocate:

1. Develop a project monitoring mechanism to collect periodic status information on all onging projects. Because current monitoring mechanisms are weak and ineffective, the new approach should have sufficient authority to enforce prompt and accurate status reporting.

2. Develop, maintain and provide AMC-wide accessibility to a CIM Reference Data Base. Information contained in the data base should include descriptions of technologies, a dictionary of CIM-related terms, a CIM bibliography organized by technology and author, a listing of personnel with specific CIM skills, descriptions of current and previous CIM projects within and external to the AMC (including a technical "lessons learned" section), a listing of educational courses and institutions for specific CIM topics and an electronic mail/bulletin board facility for exchanging information on CIM.

3. Develop a structured CIM education program for specific job classification grades within AMC. Training should be comprised of two parts. First, a reading and testing segment using textbooks at local facilities which would prepare students for an instructor-led course at an AMETA facility. A mandate to ensure completion of specific courses within a certain period of an individual's career would increase organizational effectiveness by attracting and retaining personnel with valuable CIM skills. Second, management-level education should be emphasized because, at present, current efforts are geared towards operational-level personnel.

4. Create a generic CIM planning and implementation methodology to be used in all future efforts. Requirements for and samples of specific documentation should be part of this methodology. Emphasis should be placed on a limited amount of simple, straightforward documents that collect only minimum required information. Utilizing a standard approach would ensure the most effective expenditure of personnel and financial resources.

5. Analyze and, where feasible, eliminate or simplify current policies and procedures whose complexity and lengthy approval cycles provide a barrier to CIM implementation.

6. Review and enhance, where necessary, hiring, promotion and compensation policies for CIM-related positions within the AMC to improve the talented CIM skill base. It is essential to remember that, no matter how attractive a particular technology is, it must be implemented correctly to achieve the advertised benefits. Skilled human resources drive this implementation process.

7. Develop a staff-based CIM Guidance team that will travel to AMC facilities to assist them in CIM implementation efforts. This team will be composed of a number of individuals who, besides possessing substantial skills in CIM technology, will be well-versed in efficient project management techniques. Personnel resources for this team can be obtained from various AMC commands, and external organizations. This team should report to the CIM Advocate, who will be responsible for the effective application of their efforts.

A more detailed analysis may result in additional management and technical recommendations. However, Arthur Andersen & Co. believes that these recommendations will provide the initial impetus for the U.S. Army Materiel Command to furthur enhance the producibility, reliability and maintainability of its weapon systems through the efficient application of Computer Integrated Manufacturing technology. Should the need arise, we are ready to provide additional assistance to the U.S. Army Materiel Command in this challenging and exciting area.

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3. RECOMMENDATIONS

A. PROPOSED CIM STRATEGY ALTERNATIVES

As a result of analyzing the information obtained from many different sources, a number of strengths and weaknesses were discovered for the current strategy. While the strengths and weaknesses are discussed in greater detail in the Analysis section, it is useful to highlight the major areas for improvement in the current strategy. They are as follows:

1. Lack of an officially defined strategy for promoting and implementing CIM
2. Lack of a single focal point for CIM information and guidance
3. Efforts designed to solve local problems without regard to AMC-wide benefits
4. A focus on developing "hard" manufacturing technologies as opposed to being a definer and manager of manufacturing data
5. A lack of adequate support for popular data integration standards
6. An absence of a CIM planning and implementation methodology to ensure efficient expenditure of resources
7. Numerous and complex regulations and procedures that block efficient CIM implementation efforts
8. An apparent high turnover ratio for skilled CIM practitioners within AMC
9. Inadequate efforts to encourage an effective level of CIM investment by AMC contractors
10. Educational resources, while available, are not fully utilized by management at local AMC facilities

Since the current strategy does not effectively address these problems, the AMC should look towards developing and implementing a strategy that will focus on eliminating these weaknesses.

Many different alternatives present themselves as options to the current strategy. In order to evaluate different alternatives, we have developed a Criteria Evaluation Matrix (Exhibit 1). This matrix can be used to evaluate not only the alternate strategies proposed in this section, but any future strategies as well.

The evaluation criteria are divided into two categories--primary and secondary. The primary criteria have a higher priority because they relate directly to the primary mission of the Army Materiel Command. The primary criteria are defined as follows:

- Reduce Acquisition Costs - Strategies are rated according to how well they will reduce weapon system acquisition costs--both long-term and short-term. Any strategy that increases the net acquisition cost of any weapons system will not be acceptable.

- Reduce Operating Cost - The ability to reduce operating cost and enhance maintainability will be a primary concern in rating any strategy. Strategies that increase operating cost should be offset by corresponding (or greater) decreases in costs in other areas.

- Improve Product Quality - The reliability of any weapon system is a critical factor in determining whether a strategy will be implemented. This criteria should carry the most weight since it has a direct effect on the safety of U.S. Army personnel.

- Improve Production Throughput - Any increases in productivity achieved as a result of implementing a strategy will make that strategy more attractive. Decreases in productivity must be accompanied by offsetting benefits in other primary criteria.

Secondary criteria as a group, while still very important, carry somewhat less weight than the primary criteria. Those criteria are defined as follows:

- Increase Intangible Benefits - The ability to attract and retain talented personnel with CIM skills is an example of a valuable intangible benefit. In order to receive a rating in this area, benefits should be defined to the greatest extent possible.

- o Implementation Cost - The implementation cost for any new strategy might be prohibitive to the extent that it would outweigh benefits in all other criteria. The only exception would be the product quality criteria which has a direct effect on personnel safety.

- o Implementation Risk - If a strategy fails during the implementation phase, it could have far-reaching adverse impacts. Management support for future endeavors could evaporate and the confidence and morale of the implementation team could be damaged. For that reason, high-risk projects should be broken into smaller, more manageable projects or should be moved to the end of an overall implementation schedule.

There are a number of strategies that the AMC might pursue to promote CIM. Each of these strategies would be composed of different elements. Some elements may be used in a number of different strategies. As such, it might make sense to pursue the common elements of several highly rated strategies first, to establish an infrastructure or foundation for future efforts.

The following strategic elements will be included in the alternate strategies that are presented for review.

a. Establish an Official CIM Advocate at AMC/HQ - The creation of a single person or group as a focused source of guidance in all matters relating to CIM is essential. In order to be effective, the CIM Advocate will require the authority to enforce standards and guidelines. Some ability to approve funding would also ensure coordinated progress in promoting CIM within AMC.

b. Create a CIM Information Sharing Mechanism - The ability to share information concerning progress made in the diverse and rapidly changing field of CIM is crucial. Information concerning current AMC projects, as well as information about efforts at other governmental, commercial and educational organizations, should be disseminated. This will prevent duplication of effort and will increase the knowledge level of all CIM-related personnel.

c. Enhance CIM Education Programs - Although AMETA and IBEA have developed some education programs for CIM, their efforts need to be expanded. Mandating structured training programs for different levels of personnel within AMC will improve management support, eliminate resistance based on inaccurate beliefs and increase the efficiency of CIM planners, designers and implementors. Examples of appropriate training vehicles are correspondence courses with testing administered by local training coordinators, attendance at a centralized training

institute, interactive, personal computer-based training using video-disc technology, video tapes and university courses taught at AMC facilities.

d. Develop and Communicate a CIM Goal - A statement of purpose and associated guidelines for future action in the CIM field are required for efficient application of future efforts. AMC personnel will have more confidence and less frustration if they feel that their work is resulting in substantial progress towards a realizable goal. As such, the goal should be in accordance with current AMC mission objectives.

e. Attract and Retain Personnel with CIM Skills - More AMC effort is needed to attract and retain personnel with valuable CIM skills. Enhancing the current CIM skill base will, in itself, create a substantial momentum towards the achievement of an enhanced CIM capability. A structured program that includes salary, training and assignment rotation as key features is necessary to complete for rare CIM human resources in the marketplace.

f. Develop a Methodology for CIM Implementation - An effective methodology for planning, designing and implementing CIM technology will ensure that all efforts are applied in a consistent and logical manner. It will also provide direction for staff and management personnel who are not experienced in project management. An additional benefit will be the production of standard working papers for audit and reference use.

g. Establish Policies and Procedures that Enhance the Implementation of CIM - Any overly complex or restrictive policies or procedures relating to the implementation of CIM should be relaxed in favor of guidance from a central CIM advocate and a general CIM goal.

h. Develop Alternate CIM Capital Expenditure Justification Techniques - CIM efforts within the AMC and government contractor organizations would be facilitated by providing alternate justification techniques. The traditional Net Present Value (NPV) and Return on Investment (ROI) analysis methods do not give weight to intangible benefits such as employee morale, enhanced product quality, better customer service, etc. Develop new techniques to analyze the CIM expenditure in a much broader long-term view.

i. Engage in Joint Acquisitions with Other Government Agencies for Similar CIM Technologies - The economies of scale that can be realized by sharing acquisitions of similar technologies can be very beneficial. Not only can better prices be negotiated, but a unified acquisition would have sufficient weight to enforce (or entice) contractors to adhere to various integration standards. An additional benefit would be the knowledge transfer between the AMC and other sharing agencies.

j. Sponsor Research of CIM Technology at Educational Institutions and Research Organizations - Providing financial and personnel support to a number of research-oriented activities would be a method for "getting the jump on" emerging technologies. The AMC would be seen as

being on the leading edge of CIM technology innovation, and the resultant publicity would provide some justification for future efforts. Another related technique would be to create an AMC research organization for CIM technology.

k. Mandate Certain CIM Technologies in Acquisitions of Major Weapons Systems - An effective means of persuading contractors to produce products and related technical documentation in an efficient manner is to include requirements for CIM in an RFP. A phased approach would be most suitable because it would allow the AMC to study the effects of mandating incremental amounts of CIM technology on contractor performance. The U.S. Air Force is currently pursuing this strategy in its acquisition of the B-1 bomber.

l. Provide Support to Existing de Facto and Semi-Standards for Data Communication - Many standards for data communication have been proposed and most are in some stage of development. The AMC should analyze the standards to determine which of them provides the most functionality or has the greatest popularity. Then, it should provide support in the area of funding, furnishing personnel to assist in research and promoting the use of the standard in weapons system acquisitions. The benefits of this support would be to get equipment manufacturers to produce equipment that could communicate to similar equipment without any special translation (black-box) devices. Even if the functionality of the standard is not ideal, the cost savings realized by being able to choose from a wide variety of different vendors' equipment would be substantial.

m. Allow any AMC Facility to Purchase CIM Technology within High-Level Budget Guidelines - Any AMC facility should be allowed to purchase CIM technology to fill its specific needs. The flexibility gained would allow for a rapid infusion of CIM technology into the AMC.

n. Create CIM Technology Guidance Organizations to Serve Specific Functional and Geographical Needs - A variety of organizations offering technical and funding assistance to specifically defined entities within AMC would promote CIM within their own spheres of influence. However, problems may arise when guidance results in duplicate or conflicting operations.

Now that the number of strategic elements have been defined, we can proceed to developing and analyzing overall CIM strategies. We will use the criteria evaluation matrix mentioned previously to rate the strategies and choose an optimal action plan. Each strategy will be rated for all evaluation criteria as high (+8), medium (+5) or low (+2) in a positive direction, and negative (-10) if the strategy moves the AMC in a direction opposite to the favorable nature of the criteria. The ratings for all criteria will be summed

and strategies will be ranked according to positive point totals. The subjective nature of criteria ranking makes any strategy selection a matter of opinion; however, the methodology used will allow for any interested party to rank the existing or any new strategies in a quick and efficient manner. It would be desirable for high-level management and technical experts within AMC to rate these and other proposed strategies independently. Next, a meeting should be held to discuss individual viewpoints and arrive at a consensus rating for all strategies. The AMC strategy plan would then be passed to DA and DoD levels for final approval.

The strategies selected are discussed and ranked in the following narrative. The criteria evaluation matrix follows in Exhibit 1.

1. Current Strategy - This strategy is characterized by a number of ongoing CIM projects being managed by many different organizations within AMC. A variety of groups (DCS for Production, IBEA, AMSRC, LSRC, CAD/CAM Steering Group) are giving guidance in CIM technology. Funding is shared by a number of different programs (MMT, Army Civil Works) and relatively small portions (2%) of weapon system acquisition funding is used to promote CIM technology.

   Strategic Elements: k, m, n

   Criteria Evaluation Points: 29

2. Promote Digitization of Data within AMC - This strategy is characterized by a focus of eliminating paper-based information used to acquire, operate and maintain weapon and support systems used by the U.S. Army. Instead, all information would be converted to an electronic digital format that will produce benefits in the areas of space requirements, data accuracy, data access time and data analysis. This strategy will be composed of elements that will promote the production of new data in, and the conversion of existing data to, electronic digital format. A noteworthy point is that substantial progress has already been made in the area with the combined U.S. Army/U.S. Air Force DSREDS/EDCARS program.

   Strategic Elements: a, c, d, f, g, i, k

   Criteria Evaluation Points: 41

3. Incentivize Integration Technology within AMC - This strategy is characterized by active AMC support for various data integration

standards. The objective would be to move many quasi or de facto standards into a widely accepted formal status. Key candidates would be IGES for graphic data exchange, PDES for product data exchange, MAP for a factory communication protocol, and TOP as an office and engineering environment communication protocol. The long-distance (packet switching) protocol X.25 has also gained wide acceptance. Substantial economic benefits will accrue due to equipment interoperability whenever a standard is widely accepted by a vendor and user community.

Strategic Elements: a, c, d, e, f, g, k, l

Criteria Evaluation Points: 47

4. Facilitate Contractor Investment in CIM - This strategy is characterized by providing a high level of support to contractors in their implementation of CIM technology. Current funding of CIM technology implementation at 2% of total acquisition costs appears to be somewhat low. In addition to increased funding, technical and educational assistance should also be provided. Subsequent phases of major acquisitions would accrue economic benefits due to the non-unique nature of many CIM technologies. Graphic and text data, as well as machining instructions, could be developed by one contractor in a generic electronic format in the first phase, then distributed to a variety of contractors in subsequent phases.

   Strategic Elements: a, d, f, i, h, k, l

   Criteria Evaluation Points: 44

5. Create a CIM Technology Center - This strategy is characterized by the creation of an AMC-sponsored CIM technology research and education center. It would contain examples of the latest "state-of-the-market" manufacturing and systems technology. Personnel from the AMC, government contractors and educational institutions would staff and attend this center. Its main purpose would be to provide CIM education for AMC personnel and identify AMC as a leading proponent of CIM.

   Strategic Elements: a, c, d, e, j

   Criteria Evaluation Points: 32

On the basis of evaluation points, the highest rated strategy for the AMC would be Strategy 3, Incentivize Integration Technology within AMC. Two other strategies were also highly rated--Strategy 2, Promote Digitization of Data within AMC, and Strategy 4, Facilitate Contractor Investment in CIM. Since many of these strategies contain common elements, the action plan for AMC will initially encourage progress at the strategic-element level. This will be discussed in the next section.

Exhibit 1

AMC CIM STRATEGY

CRITERIA EVALUATION MATRIX

Overall Strategy	Strategic Elements	Evaluation Criteria: Primary: Reduce Acquisition Costs	Primary: Reduce Operating Costs	Primary: Improve Product Quality	Primary: Improve Production Throughput	Secondary: Intangible Benefits	Secondary: Strategy Cost (High = Low Cost)	Secondary: Strategy Risk (High = Low Risk)	Evaluation Points	Rank
1. Current Strategy	k, m, n	Low (+2)	Med (+5)	Med (+5)	Med (+5)	Med (+5)	Med (+5)	Low (+2)	29	5
2. Promote Digitization of Data within AMC	a, c, d, f, g, i, k	High (+8)	High (+8)	High (+8)	Med (+5)	Med (+5)	Low (+2)	Med (+5)	41	3
3. Incentivize Integration Technology within AMC	a, c, d, e, f, g, k, l	High (+8)	High (+8)	High (+8)	Med (+5)	High (+8)	Med (+5)	High (+5)	47	1
4. Facilitate Contractor Investment in CIM	a, d, f, i, h, k, l	Med (+5)	High (+8)	Med (+5)	High (+8)	High (+8)	Med (+5)	Med (+5)	44	2
5. Create CIM Technology Center	a, c, d, e, j	Low (+2)	Med (+5)	Med (+5)	Low (+2)	High (+8)	Low (+2)	High (+8)	32	4

Exhibit 1

AMC CIM STRATEGY

CRITERIA EVALUATION MATRIX

Overall Strategy	Strategic Elements	Evaluation Criteria: Primary: Reduce Acquisition Costs	Reduce Operating Costs	Improve Product Quality	Improve Production Throughput	Secondary: Intangible Benefits	Strategy Cost (High = Low Cost)	Strategy Risk (High = Low Risk)	Evaluation Points	Rank
1. Current Strategy	k, m, n									
2. Promote Digitization of Data within AMC	g, i, k									
3. Incentivize Integration Technology within AMC	g, k, l									
4. Facilitate Contractor Investment in CIM	k, l									
5. Create CIM Technology Center	a, c, d, e, j									

B. CIM ACTION PLAN FOR THE AMC

Arthur Andersen & Co. proposes a number of recommendations as an action plan to implement the strategies evaluated in the previous section. The basis for this action plan is that the highly evaluated strategies in the previous section contain several common elements and, thus, can be pursued independent of any specific strategy. The overall approach promoted by these recommendations is fairly straightforward:

1. Analyze the AMC's current status in terms of promoting and implementing CIM.
2. Determine where the AMC wants to be in terms of promoting and implementing CIM.
3. Choose the most efficient mechanism in going from point 1 to point 2.

The recommendations can be broken down into two different types--management and technical. Management recommendations will address high-level strategic and organizational issues, while technical recommendations will focus on developing specific mechanisms for solving current CIM problems. Because management recommendations will provide the foundation for implementing technical recommendations, they should be pursued initially.

The management action plan consists of the following specific recommendations, which should be implemented in sequential order:

1. Create a management position within AMC/HQ titled the AMC CIM Advocate. The mission of the advocate will be to efficiently coordinate CIM efforts in the AMC. The CIM Advocate should reside at AMC/HQ, but should travel extensively to AMC facilities to communicate an awareness of and support and guidance for CIM technology implementation. Authority for the CIM Advocate should reside at the AMC command level and it should be sufficient to allow for the fulfillment of its mission. Funding approval for all CIM-related efforts would be the most efficient method to exercise this authority. Although absolute funding approval is a desirable long-term goal, it might not be feasible to implement in the short term. A more appropriate short-

term solution would be to mandate review of CIM funding requests by the CIM Advocate. An additional benefit is that the CIM Advocate would act as an information conduit for all organizations engaged in CIM activities with AMC. Also, it would serve as an easily identified CIM point of contact for organizations external to AMC. Current information flows follow a network model as illustrated in Figure 2. It is readily apparent that the current topology is not the most efficient mechanism for disseminating information. The proposed approach is illustrated in Figure 3. It employs the CIM Advocate as the hub of an "information wheel" with the spokes representing channels of information flow. This topology would provide for efficient CIM information capture and dissemination to all concerned organizations.

2. Develop and communicate an official CIM goal for the AMC. This goal is essential to ensure coordinated efforts among the many diverse and geographically isolated facilities that compose the Army Materiel Command. Current CIM efforts exhibit a tendency towards implementing solutions solely for the benefit of a specific facility, without regard to economies of scale that would benefit AMC as a whole. A properly composed and communicated goal would do much to improve coordination of individual efforts in CIM and would facilitate the efficient expenditure of limited CIM funds. An example of an appropriate CIM Goal is included in Exhibit 1. The guiding principles proposed are a variation of the three highest ranked strategies from the Criteria Evaluation Matrix and, as such, would provide a good foundation for the actual goal.

The CIM Advocate should be tasked to develop the actual goal. After approval by AMC, DA and DoD management, it should be disseminated to all AMC personnel by a method consistent with its importance.

3. Plan for and take a detailed inventory of current CIM projects within the AMC. Data collected should include types of technology, funding levels (expended and planned), funding sources, management programs, expected benefits (tangible and intangible), completion percent estimates, and involved personnel and their CIM skill descriptions. This task should be managed by an appropriate member of the CIM Advocate's staff. The method of data collection should be personal and telephone interviews combined with appropriate data base searches. Paper-based survey forms would <u>not</u> be an effective data collection technique.

4. Develop an overall strategy to obtain maximum benefit from CIM projects within total funding constraints. Wherever possible, efforts to develop similar technologies should be concentrated to avoid duplication of effort. Major emphasis should be given to cooperative efforts or joint ventures with other military services, government organizations, commercial enterprises, and research and educational institutions. Management programs and funding sources should be

Exhibit 1

CIM GOAL

"PROMOTE CIM TECHNOLOGY"

A strategic goal for the U.S. Army Materiel Command (AMC) is to enhance the producability, reliability and maintainability of products that are manufactured by or produced under the direction of the AMC by the cost-effective implementation of Computer Integrated Manufacturing (CIM) technologies. CIM is an umbrella term that incorporates many advanced manufacturing technologies and concepts. Some of the major concepts and technologies are:

- o Artificial Intelligence
- o Group Technology
- o Computer Aided Design
- o Computer Aided Engineering
- o Numerical Control
- o Flexible Manufacturing Systems
- o Simulation
- o Statistical Process Control
- o Robotics
- o Automated Material Handling
- o Manufacturing Simplification (JIT)
- o Manufacturing Resource Planning
- o Computer Aided Process Planning
- o Integration Standards
- o Adaptive Control
- o Advanced Data Collection Technology
- o Data Communication Technologies
- o Advanced Computing Technology

All AMC personnel should actively promote CIM by adhering to the following three guiding principles:

1. Provide a uniform policy for electronic format data that is used to design, manufacture and maintain Army products.
2. Promote the development and proliferation of electronic data integration technologies.
3. Promote procurement policies that will encourage contractor investment in CIM technologies when bidding on DoD-sponsored projects.

Any future CIM-related effort must adhere to these guiding principles for funding to be approved. AMC/HQ welcomes your questions, suggestions or concerns regarding this goal statement. They should be directed to the CIM Advocate, AMC/HQ, for prompt attention.

combined to eliminate confusion and enhance funding effectiveness. A prime example of where significant efficiencies could be achieved is the combination of the three independent efforts to install integrated manufacturing control systems at the Watervliet Rock Island and Pine Bluff arsenals. Another high-potential area is the cross-fertilization of efforts between AMCCOM and DESCOM whenever a commonality exists. The inventory completed in step 3 will be a vital input to this process. The CIM Advocate should create a permanent staff group to perform this task. Staff group members should be selected on the basis of three factors:

1. Knowledge of specific CIM technologies
2. Functional expertise
3. Command representation

Once the overall strategy is developed, it should be implemented without delay.

In addition to the aforementioned primary management recommendations, the AMC should pursue certain technical recommendations. The following technical action points should also be supervised by the CIM Advocate. The implementation sequence of the technical recommendations is not as important as it is for the management recommendations:

1. Develop a project monitoring mechanism to collect periodic status information on all onging projects. Because current monitoring mechanisms are weak and ineffective, the new approach should have sufficient authority to enforce prompt and accurate status reporting.

2. Develop, maintain and provide AMC-wide accessibility to a CIM Reference Data Base. Information contained in the data base should include descriptions of technologies, a dictionary of CIM-related terms, a CIM bibliography organized by technology and author, a listing of personnel with specific CIM skills, descriptions of current and previous CIM projects within and external to the AMC (including a technical "lessons learned" section), a listing of educational courses and institutions for specific CIM topics, and an electronic mail/bulletin board facility for exchanging information on CIM.

3. Develop a structured CIM education program for specific job classification grades within AMC. Training should be comprised of two parts. First, a reading and testing segment using textbooks at local facilities, which would prepare students for an instructor-led course at an AMETA facility. A mandate to ensure completion of specific courses within a certain period of an individual's career would increase organizational effectiveness by attracting and retaining

personnel with valuable CIM skills. Second, management-level education should be emphasized because, at present, current efforts are geared towards operational-level personnel.

4. Create a generic CIM planning and implementation methodology to be used in all future efforts. Requirements for and samples of specific documentation should be part of this methodology. Emphasis should be placed on a limited amount of simple, straightforward documents that collect only minimum required information. Utilizing a standard approach would ensure the most effective expenditure of personnel and financial resources.

5. Analyze and, where feasible, eliminate or simplify current policies and procedures whose complexity and lengthy approval cycles provide a barrier to CIM implementation.

6. Review and enhance, where necessary, hiring, promotion and compensation policies for CIM-related positions within the AMC to improve the talented CIM skill base. It is essential to remember that, no matter how attractive a particular technology is, it must be implemented correctly to achieve the advertised benefits. Skilled human resources drive this implementation process.

7. Develop a staff-based CIM Guidance team that will travel to AMC facilities to assist them in CIM implementation efforts. This team will be composed of a number of individuals who, besides possessing substantial skills in CIM technology, will be well-versed in efficient project management techniques. Personnel resources for this team can be obtained from various AMC commands, and external organizations. This team should report to the CIM Advocate, who will be responsible for the effective application of their efforts.

A more detailed analysis may result in additional management and technical recommendations. However, Arthur Andersen & Co. believes that these recommendations will provide the initial impetus for the U.S. Army Materiel Command to furthur enhance the producibility, reliability and maintainability of its weapon systems through the efficient application of Computer Integrated Manufacturing technology. Should the need arise, we are ready to provide additional assistance to the U.S. Army Materiel Command in this challenging and exciting area.

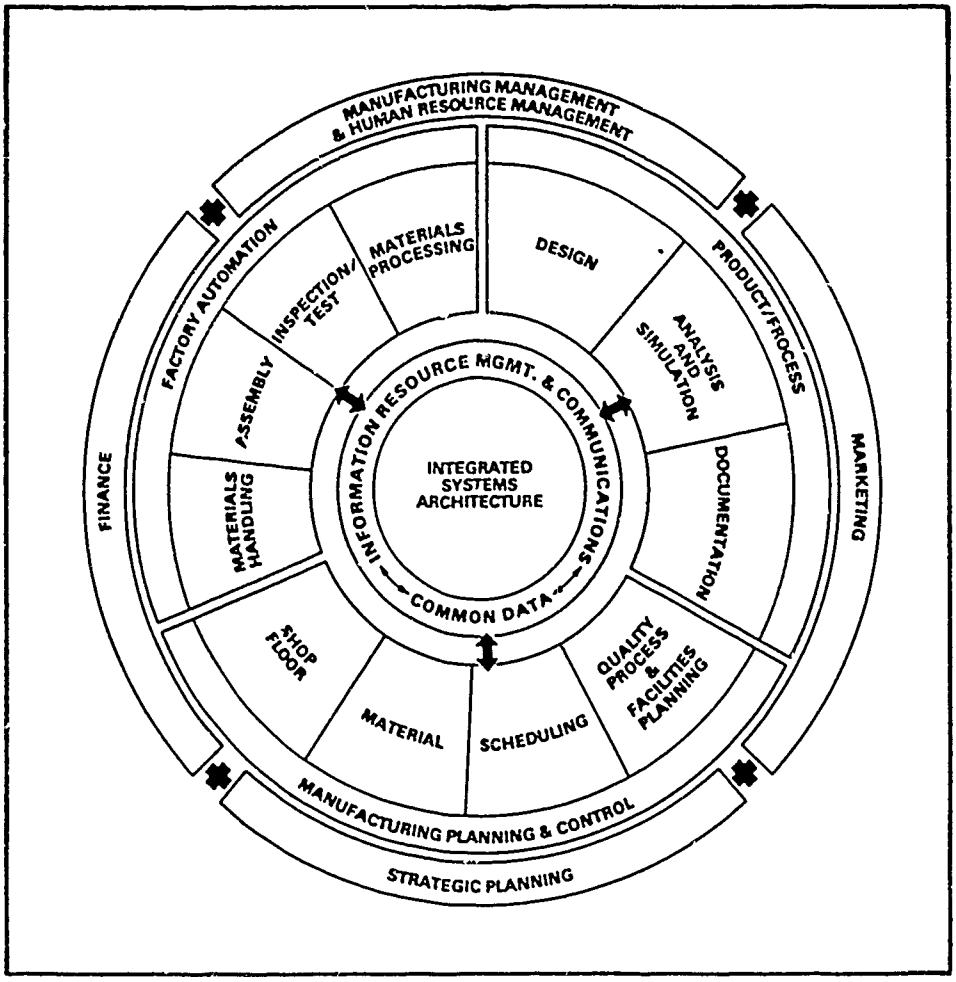
4. ANALYSIS

A. Computer Integrated Manufacturing (CIM) Technology Overview

The purpose of this briefing is to analyze the U.S. Army's strategy regarding the promotion, acquisition, development and implementation of Computer Integrated Manufacturing. Computer Integrated Manufacturing (CIM) is the coordinated application of technology to the process of design, manufacturing, distribution and maintenance for a product or group of products. The primary objectives of CIM are to improve service to customers, increase flexibility, boost productivity, enhance product quality and sustain profitable operations. Those objectives have been achieved in a variety of organizations. A study by the Manufacturing Studies Board of the National Research Council has predicted ranges for CIM benefits as follows:

- o 5%-20% reduction in personnel costs
- o 15%-30% reduction in engineering costs
- o 30%-60% reduction in overall lead time
- o 30%-60% reduction in work-in-process inventory
- o 40%-70% gain in production output
- o 200%-300% gain in captial equipment operating time
- o 200%-500% gain in product quality
- o 300%-500% gain in engineering (part and process design) productivity

An illustration of how specific functional applications are related in a CIM environment is provided by the CIM "Wheel". The CIM "Wheel" was developed by the Computer and Automated Systems Association of the Society of Manufacturing Engineers (CASA/SME). The CIM "Wheel" illustrated below, emphasizes that common engineering and manufacturing functions must be welded to an integrated systems architecture composed of a common data structure, effective data communication facilities and an information resource management organization.



CIM "Wheel"

The basic engineering and manufacturing functions focus on four major themes:

1. Factory Automation which encompasses activities such as computer numerical control, flexible manufacturing systems, robots and automated material handling systems

2. Product and Process Definition which concentrates on concepts such as group technology, Computer Aided Design (CAD), Computer Aided Engineering (CAE) and artificial intelligence

3. Manufacturing Planning and Control which focuses on processes such as material requirements planning, purchasing, materials management and Just-In-Time (JIT) techniques

4. Integrated Systems Support Architecture which is composed of hardware, software, communication and integration elements

The specific technologies that support these functional disciplines will be defined and the benefits related to their implementation will be listed. An outline of those technologies is as follows:

CIM TECHNOLOGY CATEGORIES

I. Factory Automation

1. AMH - Automated Material Handling
2. Factory Communications
3. CAI - Computer Aided Inspection
4. FAS/FMS - Flexible Assembly and Manufacturing Systems
5. Advanced Data Collection Technologies
6. Process Control

II. Product/Process Engineering

1. CAD - Computer Aided Design
2. CAE - Computer Aided Engineering
3. GT - Group Technology
4. AI - Artificial Intelligence
5. CAM - Computer Aided Manufacturing
6. TDP (Technical Data Package) Management

III. Manufacturing Planning/Control

1. MRP II - Manufacturing Resource Planning
2. JIT - Just-In-Time Techniques
3. Statistical Process Control (SPC)
4. Simulation
5. Maintenance Management
6. Quality Management

IV. Integrated Systems Support Architecture

1. Hardware
2. Software
3. Integration
4. Communications

B. Current Army Materiel Command CIM Efforts

This survey identified 42 projects currently in process or planned in the area of CAD/CAM technology. These projects are funded under the Manufacturing Methods and Technology (MMT) program. The AMC projects tend to touch on most of the CIM technologies discussed previously. The only major concentration noted was a slight emphasis on Computer-Aided Manufacturing (CAM-NC, CNC and DNC). One notable weakness is the absence of any project dealing with JIT (Just-in-Time) manufacturing simplification techniques. This is particularly bothersome, since these techniques have been proven to produce substantial short- and long-term benefits in work-in-process inventory, manufacturing lead time, manufacturing space requirements and equipment utilization. Furthermore, the successful application of many of the more advanced CIM technologies is highly dependent upon simplification of inherently complex, inefficient processes.

The major programs planned that are not listed in the accompanying summary are as follows:

- o CALS (Computer-Aided Logistics Support) - A system to be installed at a number of U.S. Army sites worldwide. It will provide a mechanism for capturing, maintaining and providing access to technical information generated during the Army material acquisition process. This program has commenced but the majority of efforts will extend well into the 1990s. The U.S. Navy and U.S. Air Force have similar CALS initiatives within the DoD CALS initiative.

- o DSREDS/EDCARS (Digital Storage and Retrieval of Engineering Data System) - A joint U.S. Army/U.S. Air Force effort to capture paper-based technical data and convert it to digital format in electronic media. Currently in progress with the first site due to come on line at MICOM in Huntsville, Alabama.

- o Army Corps of Engineers CAD Acquisition - A $120 million acquisition for the purchase of computer-aided design hardware and software to support Corps of Engineers' sites in the U.S. and overseas.

The 42 projects have the following concentrations in specific technologies (note that total of concentrations will be greater than total of projects).

FACTORY AUTOMATION

o AMH	4
o Factory Communications	3
o CAI	8
o FAS/FMS	8
o Advanced Data Collection	2

PRODUCT/PROCESS ENGINEERING

o CAD	7
o CAE	2
o GT	3
o AI	4
o CAM	18
o TDP Management	3

MANUFACTURING PLANNING/CONTROL

o MRPII	5
o JIT	0
o SPC	6
o Simulation	3
o Maintenance Mgt.	4
o Quality Mgt.	

INFORMATION PROCESSING SUPPORT

o Hardware	5
o Software	9
o Integration	3
o Communication	5

Brief descriptions of U.S. Army projects follow in Appendix B, along with descriptions of projects in other DoD services, government organizations, commercial enterprises and universities. Also included in, Appendix C, are summaries of interviews with CAD/CAM-knowledgeable individuals in various U.S. Army commands, U.S. Navy commands and commercial enterprises. These interviews provide more detailed information about ongoing CAD/CAM projects and AMC CAD/CAM strategies.

Despite the interview process, no concrete strategy for implementing CIM within AMC was discovered. The 17 individuals interviewed could not refer to a specific written policy or procedure that would have given guidance or direction in implementing advanced manufacturing technologies. Only a few interviewees were able to identify management organizations that were providing coordination for CIM activities.

Therefore, if a strategy does exist for CIM within the AMC, it is not being propagated efficiently throughout the organization. If an official strategy does not exist, then one may be imputed from the evidence at hand. That strategy would be composed of these four distinct, but somewhat interrelated, elements:

1. DoD Policy Statements
2. Ongoing and Planned CIM Projects
3. Funding Programs
4. CIM Review and Management Organizations

Detailed explanations of these elements follow.

DoD Policy Statements - Recently, several high-ranking officials at the OSD level have made policy statements indicating a general support for CIM acquisitions. Dr. Wade from the OSD stated in congressional testimony on April 23, 1986, that "we (OSD) will require each Service to develop and implement a well thought-out and planned acquisition strategy for systems that employ specific CAD/CAM capabilities."

The Deputy Secretary of Defense, William H. Taft IV, in an address to the Federal Computer Conference on September 3, 1986, stated, "Three high payoff areas are targeted for improvement:

- o Integrating reliability and maintainability design tools into the Computer-Aided Design (CAD) systems industry uses to design our weapons...
- o Automating the processes used by contractors to generate technical information...
- o Rapidly increasing DoD capability to receive, distribute and use technical information in digital form...."

These statements and others indicate that the DoD is focusing on interoperability as an important feature in all future acquisitions of computer systems and manufacturing equipment. Specifically, Deputy Secretary Taft states, "We need interoperability both on a functional level, where systems must complement one another in the exchange of information, and on a technical level, so we can replace or upgrade our systems or components without being locked into a single supplier."

The direction given by the DoD is clearly a part of the current Army strategy. In response to this direction, the Army has initiated the development of the CALS (Computer-Aided Logistics Support) system project. It is also working with the Advanced Manufacturing Research Facility of the National Bureau of Standards to develop data communication and manufacturing control system standards.

Ongoing and Planned CIM Projects - Currently, the Army Materiel Command is sponsoring or managing 42 CIM- or CAD/CAM-related projects. These projects are part of the overall MMT (Manufacturing Methods and Technology) program and receive RDTE funding. The projects cover a wide variety of technologies and are broken down by AMC major subordinate commands as follows:

- o AMCCOM 20
- o DESCOM 8
- o LABCOM 1
- o CECOM 2
- o AVSCOM 3
- o MICOM 2
- o TACOM 6
- o TSARCOM 1

These projects focus primarily on specific improvements at individual facilities; a few projects, however, have AMC-wide responsibility. As a result, overall coordination of CIM efforts is somewhat difficult. Since these projects are the physical embodiment of CIM within the AMC, an analysis of the types of technologies being implemented is appropriate. The major concentration of effort is in the area of Computer-Aided Manufacturing (CAM). Other areas of concentration are information systems software development and flexible manufacturing and assembly systems.

This compares with 53 Navy projects with concentrations in CAM, and 93 Air Force projects with concentrations in Artificial Intelligence, CAM and Systems Integration.

Project reporting is accomplished using the MMT and RDTE project data base and the MTAG (Manufacturing Technology Advisory Group) data base that is maintained by MTIAC (Manufacturing Technology Information Analysis Center). Most project descriptions were fairly thorough; however, many projects have not had updates in two or three years. A mechanism for effectively communicating technical "lessons learned" within AMC was not apparent. Interviews with members of various commands within AMC determined that there was a general lack of awareness of projects being undertaken at other commands and other facilities within the same command. Some progress has been made by MTAG to rectify this situation by sponsoring annual meetings and CAD/CAM mini-symposiums. However, these infrequent events do not alleviate the need for a real-time, up-to-date information sharing mechanism.

Funding Programs - The availability of funding is essential for AMC CIM progress. The most detailed and comprehensive CIM project cannot start without the requisite funding. The majority of U.S. Army funding for CIM

study phase programs comes from the MMT program. Funding for implementation efforts is derived from four additional sources:

1. Production Base Support Program
2. Army Industrial Funds
3. Asset Capitalization Program
4. Army Civil Works Funds

Funding for CIM is not a specific budget line item for any of the services, but 111 of 322 total RDTE projects for fiscal years 1985 through 1987 were CIM-related. The Industrial Modernization Incentive Program (IMIP) and the Industrial Productivity Improvement (IPI) programs are additional sources for CIM funding. The IMIP program supports efforts at contractor sites while the IPI program focuses on government sites. The current direction is to allow 2% of weapon system acquisition funding for the development of manufacturing technologies to improve productivity.

Funding breakdown for CIM-related programs between fiscal years 1985 through 1991 is as follows:

- o Army $54.7 million
- o Navy $82.9 million
- o Air Force $51.7 million

The source of these figures is the Congressional Testimony of Dr. Wade (Appendix D) on April 23, 1986 and they are admittedly lacking in accuracy.

An interesting point is that Army Corps of Engineers will soon award a contract for the acquisition of CAD systems that could total $120 million, but many of the AMC personnel interviewed were not aware of that program. It is also apparent that this system acquisition was not classified as CIM-related for the funding levels mentioned by Dr. Wade.

CIM Review and Management Organizations - A number of different organizations within AMC have some responsibility for coordinating CIM efforts and/or managing CIM funding. Some of the major organizations identified are:

- o AMC Deputy Cheif of Staff for Production
- o IBEA (Industrial Base Engineering Activity)
- o CAD/CAM Steering Group at AMC/HQ
- o AMSRC (Acquisition Management Systems Review Committee)
- o LSRC (Logistics Systems Review Committee)
- o AMETA (Army Management Engineering Training Activity)

External organizations providing CIM information resources are MTAG (Manufacturing Technology Advisory Group) and MTIAC (Manufacturing Technology Information Analysis Center). It was evident that, although some individuals were aware of the existence of a particular organization, no one had a substantial understanding of the purpose or objective of any of these groups. None of the groups were mentioned as barriers to or benefactors of CIM-related projects. The Computer Integrated Engineering coordinating committee of the AMSRC has been a leader in the areas of integration standards and technology definition, but its influence was felt only locally at the ARDEC (Armament Research, Development and Engineering Center) in Dover, New Jersey. When asked the question, "Who would you turn to for information about CAD/CAM technologies and funding sources?," most interviewees mentioned IBEA. However, while IBEA may be the best source for coordinating information interchange, it lacks the authority to enforce integration standards and approve funding requests.

C. CIM Efforts at Other Organizations

The other major service organizations have different approaches to promote and implement CIM technologies. The U.S. Air Force has established a specific group to manage CIM efforts. The CIM office (formerly called the ICAM group) located at Wright-Patterson Air Force Base in Dayton, Ohio, is the central coordinating group for Air Force and contractor efforts in CIM. It supervises a contractor to collect and disseminate information about CIM projects within the Air Force and promotes the benefits of CIM by having personnel speak at a variety of contractor and professional society-sponsored seminars. In addition, it has mandated the use of CIM technology in several of its major weapons acquisitions. It has promoted integration standards and implementation methodologies such as IGES, PDDI, PDES, IDEF and IISS in many of its projects. Currently, it is mandating the electronic interchange of manufacturing data in the B-1 Bomber program. In order to enhance its skills in the use of artificial intelligence, the Air Force has created the AI in Manufacturing Institute.

The U.S. Navy is in the second stage of a three-phased CAD acquisition program. The first stage, CAEDOS (Computer-Aided Engineering and Documentation System), allowed the Navy to gain considerable expertise in Computer-Aided Design technology. The next stage will provide additional experience for the final acquisition stage, which will be released in the early 1990s. Another approach used by the Navy is to release a Request for Information (RFI) to allow contractors to comment on the requirements of, and the solutions proposed by, the acquisition. As a result of information obtained in the RFI, the RFP was modified to accommodate new, higher efficiency approaches suggested by contractors. This flexibility will no doubt yield much greater long-term benefits.

Another approach used by the Navy is to assign responsibility to a specific command for developing a particular technology. In this case, the Naval Sea Systems Command (NAVSEA) is coordinating the development of CAD/CAM technology. This concentration of responsibility heightens awareness and reduces confusion about the who, what, where, when and how of CIM within the Navy.

The Department of Energy, along with a major contractor Martin Marietta Energy Systems Division, have promoted CIM as major strategic weapon. The MMES plant at Oak Ridge, Tennessee, has won the Society of Manufacturing Engineers/Computer and Automated Systems Association LEAD award for excellence in implementing CIM systems.

The use of CIM as a key element of a corporation's business strategy is becoming more and more popular. Many companies are using CIM to bring manufacturing back to the U.S. from low-wage base locations in South America and Asia. IBM Corporation, by its own admission, now has the "lowest cost, highest quality electronic typewriter producing plant in the world" in its Lexington, Kentucky, facility. One of its major goals is to achieve greater efficiencies in quality, lead time and product cost in each successive implementation of CIM. It also uses people with experience from previous CIM installations to supervise and train personnel at each new implementation. This allows them to continuously broaden their CIM technology skills while applying lessons learned from previous implementations.

Some other examples of how industry uses CIM are as follows:

- Allen-Bradley Corporation uses a "model" automated manufacturing operation in its Milwaukee, Wisconsin, facility as a marketing tool to enhance its reputation for quality and to provide its customers with a live demonstration of the benefits of CIM.

- o J I Case has created a position of Vice-President of Advanced Technology to coordinate company efforts in CIM.
- o Cincinnati Milacron has established its own consulting group to design CIM systems for customers using their manufacturing equipment.
- o General Motors acquired two different companies, Electronic Data Systems and Hughes Aircraft, to give them instant expertise in designing and implementing CIM systems.
- o Cone Drive Division of Ex-Cell-O Corporation and the Hamilton-Standard Division of United Technologies Corporation have developed and marketed software tools that allow for exchange of graphic and text data between a variety of IBM Corporation CAD and MRPII systems.

Although none of these entities has a mission similar to the AMC, it is clear that the CIM concept is very popular because of the competitive advantage it gives to successful implementors. Those organizations and many others in the U.S. are using CIM as a competitive weapon, and the majority of them have a coordinated approach to implementing that technology.

In addition to many commercial organizations, universities and colleges are also promoting CIM. Institutions such as Lehigh University, Georgia Institute of Technology, Northwestern, Stanford, Tulane, University of Wisconsin and Purdue have programs leading to a degree in CIM technology. Moreover, Arizona State University has developed a test bed for ensuring that manufacturing equipment and computer systems will work in a MAP/TOP/Ethernet environment. Many universities are sponsored by or are in joint ventures with industry to develop and apply advanced manufacturing technologies. Brigham Young University has even established a private commercial enterprise to develop and market group technology software.

D. Critique of Current AMC Strategy

Examination of the data gathered from interviews of AMC personnel and data base and literature searches has uncovered many positive aspects of the current "strategy." Specifically, those strong points are:

- o AMC personnel have displayed substantial knowledge and initiative by implementing several successful pilot applications of CIM.
- o Funding levels appear to be adequate in most cases.
- o Establishing the DCS for Production has pulled together many of the elements that are necessary for implementing CIM.
- o A positive perception of CIM benefits is present at the operational level of AMC facilities.
- o IBEA, AMETA and the MTAG are significant repositories of CIM information and personnel resources.

In contrast to these strengths, there appears to be a number of "holes" in the current Army strategy. The specific areas for improvement are:

- o The AMC has not focused on being a definer, collector and distributor of the data required to design and build weapons systems. The current focus appears to be on developing manufacturing expertise in-house, which will not be the main source of industrial capability in emergency situations.
- o The AMC does not adequately promote data integration standards that will allow it to receive and transfer manufacturing information between contractors. This will prevent enforced reliance on one contractor as the only source for a particular weapons system (e.g., FMC for the Bradley Fighting Vehicle).
- o The AMC does not have a single organization whose mission is to coordinate CIM activities within the Army. It should be able to enforce integration standards and collect and disseminate technical history data for all projects by having funding approval authority. The current melange of steering groups, funding sources and management programs tends to confuse those individuals who are attempting to implement CIM.
- o The AMC has not developed a specific methodology to be used in implementing CIM projects. Among the features of that methodology should be techniques to:

- Perform cost justification
- Assess the "as is" environment
- Model the "should be" environment
- Develop performance measurement criteria
- Standardize management reporting mechanisms

o The AMC has not undertaken substantial cooperative efforts with other government agencies who have relevant experience or similar needs in specific technologies. The CALS and DSREDS/EDCARS projects have significant potential for achieving the desired level of cooperation.

o The AMC must lend more weight to popular standards to make them actual standards. An example of this type of support would be to fund organizations performing research and development in the MAP (Manufacturing Automation Protocol). It could also develop an in-house test bed for all contractors to test the compatibility of MAP with their equipment.

o The AMC has not facilitated CIM by allowing complex and time-consuming policies and procedures for technology acquisition to remain in effect.

Specific strategies and action plans for rectifying these strategic areas for improvement are discussed in the Recommendations section.

APPENDIX A - TECHNOLOGY DEFINITIONS

I.1. Automated Material Handling (AMH)

AMH devices replace or reduce human labor normally required to transport, store, retrieve, record and manipulate material throughout the factory floor. Most common AMH equipment includes automated guided vehicles (AGVs) and conveyor systems, which transport materials between departments and feed the assembly and manufacturing processes. Automated storage and retrieval systems (AS/RS) are high-density rack storage systems with rail running vehicles that serve the rack structure for automated loading and unloading. The AS/RS can be computer-controlled to interface with robots, AGVs and conveyor systems.

Some benefits of using AMH technology are:

- o AMH replaces much of the manpower normally required in performing material handling activities. It also optimizes cell capacity utilization by enabling the continuous operation of manufacturing processes that were previously constrained by human material handling requirements.
- o AMH devices are reliable and consistent, as well as fully controllable; once programmed, they require little supervision and usually require no more than 20-25 minutes of maintenance every two to three weeks.*
- o AMH technology, particularly AGVs and AS/RS equipment, replaces or reduces the need for expensive (manually operated) trucks and forklifts; they can typically carry up to 6,000 lbs., although some are designed to carry up to 20,000 lbs.*
- o AGVs are safe to operate; bumper sensors prevent serious collisions, and warning lights and sounds provide adequate notice of vehicle presence.
- o AMH devices can transport materials to/from multiple workstations under manual or computer control. They are particularly useful in environments that may be hazardous for humans.

* Material Automation, June 1986

I.2. Factory Communications

Factory communication technologies facilitate the exchange of data between factory management personnel process control computers and manufacturing devices. The flow of data is intended to be understandable and accessible by all the devices involved, including cell controllers, NC machines, robots, AGVs and graphics terminals, even if they are supplied by different vendors.

The major elements of factory communications currently are:

- o Manufacturing Automation Protocol (MAP) - Seven-layer network specification developed by GM that conforms to ISO/OSI standard and is based on the IEEE 802.4 broadband token-passing bus network.
- o Technical and Office Protocol (TOP) - Boeing's IEEE 802.3 networking standard, which is similar to MAP, but is oriented toward office automation and engineering data processing requirements.
- o Broadband/Baseband/Carrierband Local Area Network (LAN) - A system of multiple computers that are interconnected through a broadband (which permits multiple messages to be sent simultaneously), or baseband or carrierband (permitting only one message at a time) cable in order to share access to application software, data files, peripheral equipment and external computer systems.
- o Programmable Logic Controllers (PLC), Factory, Area and Cell Controllers - These devices control the operation of and receive data from manufacturing equipment and update the central computer system with production status, statistics and out-of-limit conditions.

Some benefits of implementing automated factory communications systems:

- o They provide current production status information to management personnel, detect and immediately initiate action to resolve machine and quality problems and provide for the efficient use of production resources.
- c Factory communications standards facilitate communication between devices made by different vendors, thus providing flexibility in the selection of equipment.

- Networks speed up data exchange and facilitate the sharing of data processing from one application to another throughout the factory, and even communicate electronically with vendors and remote facilities.

I.3. Computer-Aided Inspection (CAI)

CAI is the use of computer technology to perform quality control functions in manufacturing and assembly operations. The two major types of CAI are machine vision systems and coordinate measuring machines (CMM). Vision systems employ computers and video cameras to analyze and interpret images in a manner resembling human vision.

Vision system processes consist of image formation, image preprocessing, image analysis and image interpretation. When a vision device detects a defect, it can store the defect's location in memory for subsequent analysis. Vision systems can also use X-rays to analyze the internal structure of complex products.

The most common application of vision equipment is gauging, followed by verification, flaw detection, character recognition, sorting, counting and adaptive control. The largest users of vision systems are the automotive and electronics industries, followed by aerospace, pharmaceuticals, defense equipment, food and beverage, packaged chemicals and paper products industries. (GM now uses 500 vision systems, but plans to install 44,000 systems over the next few years.)

CMM machines use robotic arms that swing around the surfaces of the part being inspected, sensing the edges of the surfaces at the preprogrammed coordinates. They then compare the observed dimensions of the part to the desired dimensions, as indicated on the design specifications.

The benefits of using CAI are increasingly evident:

- CAI systems are very accurate and consistent. They reduce the human labor component of the inspection process.

- CAI systems are effective in environments that are too hazardous for human workers. They can also perform tedious functions more consistently than human inspectors.

- The use of CAI systems has produced reductions in tool and die breakage of up to 90%. Other economic benefits are realized through better quality of products, less scrap and increased flexibility in manufacturing operations.

I.4. Flexible Assembly/Manufacturing Systems (FAS/FMS)

FAS/FMS are automated systems that provide the capability to assemble or fabricate a variety of parts in any order or quantity, as determined by product demand. They eliminate normal setup altogether, using computer control to setup and direct each machine or workstation. FAS/FMS systems rely heavily on numerically controlled machines, robotic equipment and adaptive control technology. Automated material handling and modern factory communication networks may also be employed to accommodate quick changeover and flexible processing requirements. Most observers agree that the use of FAS/FMS will grow 40% by 1990.

Some benefits of using FAS/FMS are:

- Robots replace human labor; they are not subject to fatigue, do not lose their concentration or make mistakes when performing monotonous tasks, or exhibit other human weaknesses.
- Robots' performance, output rates, as well as material input requirements, are predictable and manageable, thus reducing the concern over the quality of production and meeting scheduled output rates.
- FAS/FMS robots are easily and quickly reprogrammable to perform different jobs, such as materials handling or other fabricating operations.
- FAS/FMS systems permit rapid product changes in response to market conditions through automated machine setup and changeover. Lead time reduction in reacting to product changes averages around 40%.
- FAS/FMS systems are generally less expensive than their hard-automation equivalents that produce one type of part at a time.
- Due to their modularity, FAS/FMS systems greatly enhance the ability to accommodate expansion needs in terms of volume and variety.

I.5. Advanced Data Collection Technology

Advanced Data Collection Technology refers to methods of collecting and storing information about a product or process through the use of automated devices, such as bar code readers, magnetics, infrared scanning systems, voice recognition systems and smart cards. Bar code readers are hand-held or fixed/moving optical beams that scan computer-printed bar codes and transmit data directly into a computer. Magnetics refers to magnetic cards that have a surface on which data can be stored by selective magnetization of portions of that surface and magnetic ink character readers that use specialized circuits to sense and read information printed with magnetically-sensitized ink. Infrared scanners use temperature-sensing devices to read bar codes like symbols that are printed with a heat-retaining, carbon-based substance. In voice recognition systems, computers can accept data input by spoken command with no intermediate keying or manual data entry steps involved. Smart cards are transponders that send out radio signals conveying production data; they are activated by radio signals transmitted from a local workstation that also collects and documents the data from the smart card.

Some benefits of using the advanced data collection technologies are:

- Acceleration of material processing by identifying parts and recording inventory transactions in a fraction of manual data recording time.
- Voice recognition systems do not require the use of hands, enabling the individual to perform unrelated manual operations simultaneously. The systems interact with many popular software programs and have a large vocabulary. Data entry is faster and causes relatively fewer errors.
- Smart cards do not require any human assistance and enable data collection in environments that are not conducive to bar coding.

- Standardization of bar coding symbologies improves data communication between vendor and customer organizations.

- Magnetic and infrared scanning devices are useful in very high speed, low light or environmentally hazardous applications.

I.6. Process Control

The use of servo-mechanisms, sensors, factory communication networks, programmable logic controllers, and mini- and microcomputers to automatically control fabrication and assembly processes in a factory. Applicability of this technology includes process, flow and discrete batch manufacturing.

Benefits of process control include:

- Reduced direct and indirect labor content
- Increased product quality
- More efficient production management due to the ability to collect and analyze realtime process control information

II.1. Computer-Aided Design (CAD)

CAD denotes the use of computer graphics in the creation, modification, analysis and optimization of engineering designs. Modern CAD systems are based on interactive computer graphics, which is used to create, transform and display data in the form of pictures or symbols. They also incorporate two- and three-dimensional drafting, solid modeling, numerical control, robotics programming and distributed graphics capabilities. CAD data can be electronically transferred to the manufacturing floor, saving time and paperwork while reducing transcription errors. CAD systems from different vendors can communicate with each other by adhering to Initial Graphics Exchange Specification (IGES) that was developed by the National Bureau of Standards.

Some of the benefits of CAD systems are:

- Increased productivity of the designer, which translates into lower design costs and shorter project completion times. CAD helps the designer to visualize the product and its component subassemblies and parts; it reduces the time required to synthesize, analyze and document the design.
- Improved quality of design. CAD permits more thorough engineering analysis and investigation of a larger number of design alternatives; design errors are also reduced through the use of automatic checking systems.
- Improved communications. CAD enhances the quality of engineering drawings by providing for more standardization, better documentation of the design, fewer drawing errors and greater legibility.
- Simultaneous creation of a data base for manufacturing. In the process of creating the documentation for the product design--dimensions of the product, material specifications, bills of material--much of the required data to manufacture the product is also created.
- Improved control and quicker implementation of engineering changes. CAD provides for better documentation and direct communication with the manufacturing data base.

II.2. Computer-Aided Engineering (CAE)

CAE is the analysis of a design drawn from a CAD system. It is used to check for errors and optimize manufacturability, performance and economy of the design. CAE analyzes the functional characteristics of a part, product or system under design, and simulates its performance under various conditions. CAE can be used to determine section properties, moments of inertia, shear and bending moments, dimensions and center of gravity, as well as precisely determine loads, vibration, noise and service life cycle early in the design cycle so that components can be optimized to meet those criteria. The most powerful CAE techniques include finite element modeling (FEM) and finite element analysis (FEA).

FEM entails the creation of mathematical models to represent small, simple elements of a design, including its attributes and boundary conditions and loads. The FEA determines the impact that various environmental conditions have on the FEM. Graphic display of FEA results are used to enhance the output of the simulation process.

Benefits of CAE are:

- CAE enables the detection of design flaws and structural shortcomings of products while they are still in the design stages. This will reduce the need for prototypes, while shortening the lead times associated with design conception, creation, approval and production.
- CAE ensures that designs are released to manufacturing only after thorough testing and analysis, thus guaranteeing high levels of quality and customer satisfaction.

II.3. Group Technology (GT)

GT is a coding and classification system used to combine similar, often-used parts into families. Grouping of similar parts in a family allows them to be retrieved, analyzed, modified and manufactured more efficiently.

GT principles can be used in a variety of areas including product design, manufacturing engineering, plant layout and purchasing. A related application of GT is computer-aided process planning (CAPP), which identifies opportunities for cellular manufacturing and developing process plans to take advantage of product similarities.

The benefits of Group Technology are:

- Rapid design retrieval from the classification data base. By locating duplicate and very similar parts, GT eliminates design redundancy and helps prevent trivial design variations.
- Better control of purchased items and materials, thus reducing inventory investment and purchasing costs.
- Rationalization of product and assembly design, as well as the development of common tooling and routings. GT facilitates the development of cellular manufacturing based on product families, leading to shorter lead times, reduced work-in-process inventory and greater machine utilization.
- GT generates economic benefits such as (on average):
  - Scrap and rework reduced by 75%
  - Setup time reduced by 60%
  - NC programming effort reduced by 48%
  - Tooling costs reduced by 35%
  - Design engineering effort reduced by 20%
  - WIP inventory reduced by 40%

II.4. Artificial Intelligence (AI)

AI denotes the ability of computers to simulate the human thought process, reason, make judgments, even learn, without attempting to duplicate the uniquely human problem-solving attributes. AI research centers on several areas:

- Expert systems, in which computers are able to analyze input and provide expert advice on the basis of decision rules entered earlier by a human expert on the particular subject.
- Natural language processors, in which computers are able to understand conversational English language commands.

Current applications of AI include assisting in VLSI design, production control, medical diagnosis, order entry, FMS design, data base queries, performance monitoring, equipment repair and any other application that has a distinct and documentable methodology.

Some benefits of using AI are:

- AI makes decision making faster and more efficient; it detects and diagnoses problems, recommends corrective action, and is more consistent in decision-making processes.
- Expert systems reduce dependency on human experts; they examine more decision rules simultaneously and do not forget or have preconceived notions in decision making that might impede objective reasoning.
- AI enables fewer individuals to oversee and control larger, complex environments.
- Natural language processing systems eliminate the need to train individuals in technical aspects of computer programming and/or data entry functions.

II.5. Computer-Aided Manufacturing (CAM)

CAM refers to the use of computer technology to plan, generate and control manufacturing processes. CAM can involve production scheduling, manufacturing engineering, industrial engineering, facilities engineering and quality control. It includes several categories of factory automation, of which numerical control (NC) programming, adaptive control and interfaces to CAD systems are the most significant.

Adaptive Control systems is a manufacturing control method where a machines' control parameters are continuously and automatically adjusted in response to feedback of measured process variables. An example might be where the depth of a cut is adjusted based on tool bit wear which was automatically sensed by measuring a particular dimension.

NC machine tools are programmed using computer languages such as APT and COMPACT II. Computer Numerical Control (CNC) systems use computers to store machining instructions and control manufacturing devices. These operations were performed using punched code mylar and paper tape in earlier NC systems. Direct Numerical Control (DNC) systems, in which the computer programs are stored in a shared memory area for downloading when necessary, presents an ideal solution for Flexible Assembly/Manufacturing System operations.

Direct interface with the CAD/CAM data base automates the transfer of engineering designs to the manufacturing process, eliminating most of the human labor requirements and ensuring high levels of design quality and integrity.

Among the many benefits of CAM are the following:

- Machine capacity utilization is higher due to automated retooling and setup. The reduction in setup time translates into shorter lead times, less downtime, smaller work-in-process inventory and greater productivity.

- Material control is more effective due to more accurate planning of requirements. CNC machines consume material and produce output at predictable rates, making it easy to forecast material usage and manage inventory levels.

- CAM ensures consistent quality of output due to the programmable and self-corrective nature of CNC machines, and the efficient transfer of design from the CAD/CAM data base.

II.6. Technical Data Package (TDP) Management

TDP Management refers to the control and manipulation of documents containing technical information for a manufactured or purchased product. Most recent technological developments allow the data to be stored and transferred electronically through the use of computer terminals linked to networks. Updates to TDP and engineering changes can be performed online, as can inventory and shop floor transactions pertaining to TDP-referenced production orders.

A complete TDP consists of all applicable technical data, i.e., plans, engineering drawings and associated lists, specifications, purchase descriptions, models, standards, performance requirements, quality assurance provisions and packaging data. The data contained in a TDP is used to support the following functions:

- Procurement - Item specifications, delivery schedules, purchasing methods
- Production - Shop order documentation, bills of material, routings, material requisitions, item specifications, production schedules, rates and lead times, and equipment requirements
- Installation - Specifications of environment
- Maintenance - Repair limits, procedures, quality requirements
- Provisioning - Product identification documentation
- Transportation - Necessary data and clearance drawings for transportation guidance
- Development - Interface and functional requirements
- Configuration Management - Engineering changes

Benefits of using TDP Management technology are:

- o Reduction or complete elimination of production order paperwork
- o Uniformity in design and manufacture
- o Accurate and up-to-date production statistics reporting
- o Coordinated, simplified implementation of engineering changes
- o Facilitation of configuration audits and revisions
- o More efficient diffusion of technical production and engineering data

III.1. Manufacturing Resource Planning (MRP II)

MRP II is a method for the effective planning of all the resources of a manufacturing company. It connects the complete set of functional subsystems found in most large business enterprises, including Business Planning, Production Planning, Master Production Scheduling, Material Requirements Planning, Capacity Requirements Planning and associated modules. Hence, it is often referred to as a "closed-loop manufacturing" system. The output from MRP II is integrated with various financial reports, business plans, inventory and budget projections to enhance the effectiveness and analytical scope of the manufacturing management process.

The benefits from using MRP II are:

- MRP II integrates the major functional disciplines within a manufacturing company; it establishes and maintains a channel of information between departments, keeping the principal planners and supervisors fully informed of the needs, intentions and constraints of the organization.
- Improvements of 20%-40% in the number of on-time deliveries. MRP II provides for accurate and flexible scheduling of manufacturing operations by tracking the production schedules closely to actual performance.
- Improved quality yield of 10% to 20%. MRP II checks for configuration accuracy, from materials planning and procurement through shop floor operations.
- MRP II provides information to control operations, react to changes quickly and identify and correct bottlenecks in the work flow.
- Reduced manufacturing overhead costs of 10%-30%. MRP II helps lower inventories, reduce storage space and minimize both obsolescence and scrap.

III.2. Just-In-Time (JIT) or Manufacturing Simplification Techniques

JIT is the name given to a manufacturing system where the parts needed to complete a finished product are produced at or delivered at the assembly site exactly when needed. This philosophy, used extensively in Japan, is based on the pursuit of elimination of all non-value-adding tasks inherent in the conventional production process. Significant improvements have been made in the areas of work-in-process and finished goods inventories, setup, queue and lead times, transit times and distances, and excess factory space.

JIT makes extensive use of group technology, process control methods, and organizational dynamics to achieve the reductions in process lead times. Assembly and manufacturing cells are arranged in U-shapes or serpentines to minimize transport requirements. JIT strives to minimize lot size quantities and produce only as much as is immediately required to cover demand in the current period. It is a "pull"-based system where KANBAN cards replace conventional shop orders. These cards indicate which parts and quantities are needed to satisfy short-term customer demand.

The benefits of applying JIT concepts are:

- Reduction of labor costs by 10%-30%
- Reduction of work-in-process inventory by 80%
- Reduction of overall inventory requirements by 90%
- Reduction of setup requirements by 75%
- Reduction of production lead times by 90%
- Reduction of manufacturing space requirements by 50%
- Improved product quality of 70%-80%

III.3. Statistical Process Control (SPC)

SPC is the use of statistical methods in monitoring and reporting on the effectiveness and quality of production processes. The goal of SPC is to ensure that processes are in control, and thereby eliminate production of nonconforming material. Computers and advanced data collection technologies have enhanced the data collection and analysis components of SPC. An example is a computer that collects a steady stream of operational data from several workstations and applies statistical analysis to document the process condition. SPC systems can also gauge compliance with predetermined requirements, monitor productivity of both the machine and operator, perform variance analysis and print summary reports. They can also detect disallowable variations from stipulated parameters and direct the operator to make adjustments that will bring the process within the target area.

Some benefits of using SPC are:

- SPC enables companies to reduce their quality control activities and staff by 15%-18% within one year. It is a way to cut labor costs and remove the human error element, while ensuring high standards of process and product quality.
- SPC and measurement data is immediately available to users through video display terminals or printers. This enables users to take corrective action before product quality or production rates fall below acceptable levels.
- A by-product of SPC is current production status data such as item counts as they come off a specific machine.

III.4. Simulation

Simulation refers to the process of designing and utilizing a representative model of a system to reproduce the actual conditions of the system. It is used to observe and evaluate the behavior or performance of a system under different operating policies and conditions. The major advantage of computer simulation is that it allows an analyst to experiment with changes to a model under observation without actually making changes to the real system. The stages of simulation model development are model building, data acquisition, model, validation, experimentation and analysis of results. The model can be of a manufacturing process, transportation system, network system and any other system that can be defined by a set of operating rules.

Computer simulation is being increasingly applied in manufacturing environments to analyze engineering designs of products and facilities, monitor and schedule production flows, and evaluate the capabilities and limitations of manufacturing systems. Simulation systems can be integrated with CAD/CAM systems, robotic workcells, production scheduling and facilities planning systems, as well as other systems.

Some examples of applications are:

- o Capital investment evaluation
- o Workstation sizing
- o Batch sizing
- o Material handling design
- o Bottleneck identification
- o Product mix evaluation
- o Computer/communication sizing

The benefits of simulation include:

- o More efficient design of systems and end products. Simulation enables designers to completely test the performance of a system under all

anticipated circumstances prior to implementation. This permits extensive design iteration without capital-intensive prototype construction.

- Better control of systems in operation. Simulation detects potential problems in production before they occur, allowing for timely system adjustments. Additionally, simulation reacts quickly to unexpected events in the system, by identifying the problem, explaining the underlying causes of the problem, and determining the appropriate corrective action.

- Cost savings due to more smoothly functioning production operations and reduced work-in-process bottlenecks.

III.5. Maintenance Management

Maintenance management refers to activities intended to eliminate disruption of the manufacturing operations caused by breakdowns or faults in the various plant equipment and machinery. It is concerned with keeping the production facilities in adequate working condition and may include tests, measurements, replacements, adjustments and repairs as necessary. An increasingly important area of maintenance management is preventive and predictive maintenance (PPM), which denotes the scheduling of maintenance at regular intervals regardless of the condition of the equipment. PPM can include both minor operations like lubrication and inspection, and major jobs like the overhaul of a machine. It is designed to prolong the operating life of the equipment and eliminate the potential causes of breakdowns and inadequate performance.

There are four basic elements of a maintenance management system: maintenance labor, plant equipment, maintenance inventory and maintenance information. Maintenance labor requires the effective use of work measurement, planning and scheduling, and performance monitoring. Plant equipment management requires evaluation of the PPM needs and implementation of a formal PPM program. Maintenance inventory needs to balance the service level requirements with inventory carrying costs. Maintenance information provides management with a tool to make effective decisions on maintenance-related capital expenditures.

Benefits of effective maintenance management are:

- Reduced machine downtime normally caused by failures and emergency repairs

- o Reduced maintenance cost due to a reduction in major repairs
- o Extended equipment life due to better management of the plant resources

III.6. Quality Management

The objective of quality management systems is to reduce or eliminate scrap and rework requirements from the manufacturing and assembly areas. The technique involves collecting process data so that any variables causing product defects can be isolated and corrected. There are several major elements of an effective quality management system. Total Quality Control (TQC) refers to JIT systems where a single part's quality problem causes the entire production process to be shut down until the problem is resolved. Quality Circles are groups of manufacturing and inspection personnel that meet regularly to discuss quality problems and potential resolutions. Statistical Quality Control (SQC) is the use of statistical techniques to measure the quality of parts through automated monitoring of machine processes.

Some examples of automated quality assurance techniques currently being used in various industries:

- Automatic verification of material qualification, employee rating, tooling version control, calibration status and process certification
- Automatic acquisition/management of inspection results
- Automatic creation of discrepancy documentation
- Automatic recording, processing and reporting of manufacturing performance reports
- Automatic generation of inspection instructions/programs

Benefits of effective quality management systems include:

- Reduced or eliminated scrap and rework requirements due to better quality monitoring of the production process
- Reduced manual inspection requirements due to automation of the quality control functions

- Improved customer service, due to incorporation of quality considerations into the design of the product
- Lower production costs due to tighter control over product quality

IV.1. Hardware

Revolutionary advances in computer hardware technology are making information processing and systems integration more efficient than ever before. Developments in circuit design and fabrication have led to dramatically improved performance of computer systems in terms of processing power, speed, cost per function, reliability and environmental adaptability. Supercomputers, such as the Cray-2, are being developed that are 10-20 times faster than conventional computers and cost one-fifth less per FLOP than large mainframe computers.

Additionally, microprocessor chips, such as the Intel 80386, are adding significant processing power to microcomputers by enabling them to perform both segmentation and paging memory techniques, a feat previously accomplished only by mainframe computers.

Other techniques that significantly improve the performance of computer systems include the development of minicomputer clusters. They provide the ability to incrementally expand system capabilities until mainframe performance levels are reached.

Recent efforts have focused on improving the performance of CPUs by reducing the complexity of instruction sets the CPU hardware must execute. Computer systems are being developed with RISC (Reduced Instruction Set Computer) architectures, where low-level machine instructions that require more than one cycle (just long enough to allow a register-to-register operation) are deemed too complex and are delegated to higher level software layers. In addition to RISC, parallel processing systems are gaining significant attention. These systems attempt to reduce the run-time of a single

logical task by dividing it into a number of subtasks that can be executed concurrently. Conventional multiprocessing systems, where run-time is accelerated by concurrently executing unrelated tasks or jobs, can be equipped to handle parallel processing tasks.

Exception handling techniques of processors are also being improved, leading to the development of Fault Tolerant Processors. These computers detect faults in software and hardware performance and continue to process information instead of aborting the runs and producing data "dumps." They are also capable of reconstructing events leading to exceptions and compiling run statistics for documenting the faults.

Benefits of developments in computer hardware technology are illustrated in their effects on computer system operations, such as:

- Improved computer system price/performance ratios.
- The ability to solve problems, perform complex tasks and pursue applications that were previously impossible or excessively difficult.
- Improved support for the integration of factory automation technologies, resulting in greater benefits in terms of performance and cost-effectiveness.

IV.2. Software

Current trends in information systems applications reflect the increasing importance of computer software products that enhance the benefits of integrated factory automation. Important software developments include data base management systems based on relational data models and more efficient realtime operating systems, such as UNIX and its derivatives.

Relational DBMSs, such as DB2 for mainframes and dBase III for microcomputers, use very simple file structures that are in the form of matrices or "tables." Each row of a table represents a unique record housing a fixed number of unique fields. Relationships may be created dynamically between any two tables that contain a common data field. The relational approach to DBMS is gaining widespread popularity among vendors and users alike and is expected to become the dominant force in information management systems design.

The UNIX operating system is attracting substantial attention for its realtime, multi-tasking capabilities. UNIX is widely considered as the leading system for accommodating the communications interface requirements of the sixth (presentation) functional layer of Manufacturing Automation Protocol (MAP).

There are significant benefits attached to the use of relational DBMSs and realtime operating systems like UNIX, including:

- Relational DBMSs provide the flexibility that is necessary to accommodate numerous iterations of systems development and integration between applications.
- Relational DBMSs provide the ability to access and manipulate data files at the table level rather than on a record-at-a-time basis, as is usually the case in hierarchical and network models. They take

full advantage of the segmentation of data into usable pieces (tables) that can be retrieved and combined when necessary.

- Unlike hierarchical DBMSs, relational DBMSs are not built with a limited number of logical views or access paths. Their access paths are specified by the user. Furthermore, relational DBMSs do not use indexing; therefore, their performance is not hindered by maintaining pointers.

- Relational DBMSs use simplified, English-style command sets that eliminate the need for detailed, procedural instructions.

- Relational DBMSs are based on logical rather than physical structures and they show the relationships between items. Data is represented in tabular form and new relationships can be easily created. Searching is generally faster than with other DBMS models, modification is more straightforward, and the clarity and visibility of the data base is improved.

- UNIX is a multi-user, multi-tasking, realtime operating system that enables the processing of application programs on multi-vendor hardware, even when the programs were developed using a particular hardware device. It processes applications at a fraction of the speed of conventional operating systems and facilitates instantaneous updates and queries of data base records.

IV.3. Integration

Integration of the various factory communication networks, engineering and manufacturing data bases, and information processing systems is key to successful CIM implementation. In order to make integration of CIM technologies feasible and practical, several configuration models have been developed to provide guidelines for vendors and end users of CIM technologies. The Manufactu ing Automation Protocol (MAP) is emerging as a widely accepted factory communications standard, facilitating communication links between the seven layers of functional interfaces in ISO's Open Systems Interconnection model. The Technical and Office Protocol (TOP), while identical to MAP in all but two layers and its use of different carrierband topology, is MAP's counterpart for office and conventional data processing applications. The Initial Graphics Exchange Specification (IGES) is a standard developed by the National Bureau of Standards that permits exchange of graphic data between different CAD systems. Product Definition Data Interface (PDDI) is a standard developed by the U.S. Air Force's ICAM group that permits exchange of manufacturing data between CAM systems. The Integrated Information Support System (IISS) is another ICAM-sponsored model designed to facilitate the integration between different types of information processing systems. ICAM Definition (IDEF) Methodologies are analytical tools used during a project to analyze current manufacturing operations and propose changes in system design for future operations.

The benefits of conformance to standards of communications interfaces are:

- Ability to transfer information between hardware supplied by different vendors, making the acquisition of equipment more selective and encouraging competition among vendors, thereby generating cost efficiencies.

- Ability to transfer information between all operational levels of a manufacturing company.

- Improved decision making due to an ability to transfer information more efficiently. A key element of this benefit is rapid feedback on the potential effects of the decision so that changes can be made faster and with less cost.

IV.4. Communications

Trends in communications include use of fiber optic links, satellites, X.25 protocol, digital high-speed lines and micro-to-mainframe computer interfaces.

Fiber optic links use light-emitting diodes (LEDs) or lasers to send data in the form of light over glass fibers. The bandwidth of fiber optic systems depends on the fiber optic chip receiver circuits. As this technology improves, the bandwidth of a fiber optic system can be increased by replacing this circuit. Since bandwidth and data transmission capacity are related, fiber optic systems can move large quantities of data very quickly. System capacities of 565,000,000 bits per second are currently available.

For long-distance data transmission, communication satellites are still the most efficient transport mechanism. Space can be leased on satellites from a multitude of vendors as needed.

The X.25 packet data protocol provides a standard interface to set up packet networks using equipment from multiple vendors.

High-speed digital lines allow faster, more accurate transport of data than their older analog counterparts. Capacities of 10 to 20 mbps make remote processors a viable solution for graphics applications. Introduction of Integrated Services Digital Network (ISDN) standards provide a single solution for combined voice, data and graphic transmission problems. Current system capacities provide standard 144 Kbps and 1488 Kbps interfaces to the public network.

Benefits yielded by the developing technologies are:

- Increasing bandwidth of fiber optic systems and high-speed lines allows for faster, more economical data transport.
- The increasing use of standard protocols allows for more efficient machine-to-machine communications and use of multiple vendor equipment.
- Micro-to-mainframe computer interfaces provide more efficient use of computer resources. Realtime intensive programs, such as spreadsheets, can be run on a dedicated micro while shared data bases are available to all users on the mainframe.

APPENDIX B - CIM PROJECT SUMMARIES

U.S. ARMY PROJECTS

DESCOM

- In-depth engineering study at a depot (Letterkenny) to implement state-of-the-art CIM equipment and process technology in establishing an advanced technology model depot facility (MDF).

- Replacement of existing equipment, and upgrading of facilities (Anniston) with state-of-the-art equipment and associated operating methods.

- Analysis of a depot (Tooele) with a focus on productivity improvement, cost and time savings, and plant modernization. Development of statistical process control methodology, technical reports, computerized standards and MIS system enhancements, and implementation of computer-aided inspection systems.

- Establishment of flexible manufacturing systems for the manufacture of low-cost C3 equipment through the application of computer-aided manufacturing (CAM) systems, group technology and intelligent robots.

- Installation of robots to perform the welding operations in the M113A2 suspension product manufacturing process (Red River Army Depot).

- Installation and programming of robots to speed up the curing process for M88/M48/M60/M1 track blocks (Red River Army Depot).

- Analysis of a depot (Corpus Christi) to develop an integrated modernization plan, design specifications for a facility information control system, and a project management plan and a training program.

- Development of an automated engine block machining system for overhaul applications (Tooele Army Depot).

- Design and installation of a machining system capable of computer-actuated configuration changes for tightening of engine container bolts without requiring significant human labor (Tooele Army Depot).

- Development of a manufacturing process that will utilize vision-based systems to inspect finished reticles used in the manufacture of semiconductor photomasks.

- Establishment of fully automated shop facilities for the inspection, repair and testing of printed circuit boards (PCBs) used in electronic weapon systems (Sacramento Army Depot).

AVSCOM

- Modernization and automation of helicopter manufacturing facilities (Hughes Corp.) utilizing CAM systems, improved production planning and control, and improved material handling and inventory control techniques.

- Development of a CIM factory design methodology to assist in designing CIM cells and calculating economic return on the cell investment. Simulation techniques and group technology software will be used to analyze cell production flows (AVSCOM).

- Development of a CAM process to include the automated capability for the fabrication of AH-64 electrical wire harnesses.

TSARCOM

- Analysis of an engine plant (Stratford) with a focus on productivity improvement, cost savings and plant modernization through implementation of modern MIS and CAM systems.

CECOM

- Implementation of a computer-aided process control system for the fabrication of varactors and pin diodes.

MICOM

- Implementation of robotics, bar coding, area and cell controllers, computer-aided inspection systems and modern MIS equipment in the development of a CIM facility for the fabrication of wire harnesses (Redstone Arsenal).

- Analysis of plant modernization opportunities to reduce the unit production costs of the Hellfire weapon system.

TACOM

- Development of a model flexible manufacturing system to demonstrate and document automated fixturing capabilities in establishing a national standard for automated design and assembly of fixtures (National Bureau of Standards).

- Implementation of a computer-aided design (CAD) and engineering (CAE) system with finite element analysis (FEA) capabilities for use in finalizing the cold forging process of gears.

- Development of techniques for designing the forging process and manufacturing the forging dies through integration of CAD and CAM technologies.

- Implementation of a computer-aided control and inspection (CAI) system to automate the dynamometer test cells and reduce the rebuilt engine acceptance test time.

- Implementation of CAD, CAM and CAI technologies to provide more economical manufacture of the Bradley Fighting Vehicle.

AMCCOM

- Establishment of a computer-aided process planning (CAPP) system to determine the most efficient manufacturing processes for meeting specific performance criteria (CRDEC).

- Integration of state-of-the-art automated handling, robotics and CAI systems, as well as technical data package (TDP) management techniques in the development of an automated assembly system for the production of microminiature millimeter wave transducers (ARDEC).

- Installation of a CAM system to provide automated process control of machining operations (Rock Island Arsenal).

- Implementation of a weapons system's parts classification system based on group technology concepts (Benet Weapons Lab).

- Development of a prototype machine tool by retrofitting a cylindrical grinding machine with an adaptive control system to control the wheel speed, sharpness and cutting efficiency (Watervliet Arsenal).

- Implementation of an integrated CAM and CAI system to permit in-process gauging of tool paths and the direct adjustment and control of tool functions (Rock Island Arsenal).

- Integration of CAD/CAM technologies for manufacture of cannons. The CIM system will operate under a distributed numerical control (DNC) system and eliminate punched tape from the shop floor. Online maintenance diagnostics, adaptive control technology and interactive graphics for inspection will be used to facilitate realtime management of the system (Watervliet Arsenal).

- Implementation of CAD, CAE and expert systems (artificial intelligence) to improve the design and fabrication quality of steel castings (Rock Island Arsenal).

- Implementation of statistical process control (SPC) and quality control (SQC) systems, combined with adaptive control technology, to monitor machining operations and automatically adjust for machine tool errors (Watervliet Arsenal).

- Installation of programmable logic controllers to provide process control feedback for the chrome plating processes of cannons (Watervliet Arsenal).

- Design and installation of an integrated manufacturing system (IMS), utilizing data base management systems, simulation, and state-of-the-art materials management techniques (Rock Island Arsenal).

- Installation of a data base management system with online access capability. Appropriate hardware and software will be installed, followed by installation of automated applications in manufacturing process planning, time standard generation, facilities planning and production control simulation (Rock Island Arsenal).

- Evaluation of existing fire control items' manufacturing systems and development of alternate processes based on latest technology (ARDEC).

- Implementation of CAI and CAPP systems for manufacturing small-caliber weapons' components, as well as development of an automated feedback system to transfer data from automated bore straightness inspection devices to computer-controlled straightening machines (ARDEC).

- Implementation of CAD techniques to design dies that will tolerate high forging temperatures (Rock Island Arsenal).

- Development of a flexible machining system that will provide overall tool management and integrate quality control, material handling, assembly and testing reporting systems (Rock Island Arsenal).

- Design and installation of a computer control system to monitor electrode power and determine melt additions and temperature changes in furnaces producing casting parts (Rock Island Arsenal).

- Design and implementation of a plant/machinery monitoring system with dynamic, online analysis capabilities (Watervliet Arsenal).

- Development and integration of CAD, CAE and GT systems, along with CAPP, MRP II and DBMS and LAN technologies to produce the most modern cannon-making facility in the world (Watervliet Arsenal).

U.S. GOVERNMENT AGENCY PROJECTS

U.S. Navy (52 projects) (plus NICAM2 and CAEDOS)

- Development of a computer-controlled process to manufacture thick film hybrid circuits
- Development of a computer-aided automatic manufacturing process for the production of GaAlAs (Gallium Aluminum Arsenide) LEDs (Light Emitting Diodes)
- Development of a computer-aided automatic manufacturing process for Microwave Circuit Board (MCB) assembly
- Development of an automated PCB fabrication line
- Development of a DNC process for automated drilling of wings on the AV-8B aircraft
- Develop precision robotic technology to aid in the manufacture of composite parts for fighter aircraft
- Develop a Flexible Manufacturing System (FMS) for the manufacture of small batch metal parts. Demonstrate those concepts in a highly accessible national center
- Develop an Automated Ply Laminating System (APLS) that will reduce the cycle time of cutting, sorting and laminating ply shapes from composite materials
- Analyze cost-driving elements of a contractors' manufacturing facility and identify areas where AMT could be applied to achieve efficiency improvements (2 projects)
- Develop iconic models of automated material handling equipment to simulate system dynamic response
- Design and construct a CNC machine tool to automate the joining process for complex pipe joints
- Design and program a fixed base robot to weld rigidly fixtured parts
- Design a robotic welding process for shipbuilding applications that uses vision and adaptive control
- Design and fabricate a robotic plasma arc cutting process for use with structural steel
- Analyze use of AMT (CAD/CAM) to integrate design information (text and graphics) with plant floor manufacturing operations

U.S. Navy (cont'd)

- o Analyze the use of flexible assembly/manufacturing systems to enhance ship-building operations
- o Research ship design functions to determine the applicability of applying computer technology
- o Determine how group technology concepts can be applied to expedite the component assembly and installation process aboard ships
- o Develop and present a seminar on the application of computer graphics technology in the ship-building industry
- o Develop adaptive control techniques to improve quality of robotic welding
- o Develop Artificial Intelligence/Expert System to control robotic welding systems
- o Analyze how improvements in computer technology can be utilized to improve efficiency in design and manufacturing operations
- o Determine how Artificial Intelligence and Adaptive Control can be combined to enhance robotic welding systems
- o Develop software to automatically generate robot control programs that are used in robotic arc welding applications
- o Develop a research center to perform productivity and technical and economic feasibility studies for all areas of electronics manufacturing
- o Promote the EIA RS494 standard for Binary Cutter Location (BCL) files as a means to allow common usage of NC data between machine tools of different manufacturers
- o Develop a system to optically scan a parts 3-D geometry and convert that data into an engineering drawing in an IGES-compatible format
- o Design and implement a computer-controlled machine to cut and form chaff brindles
- o Develop system for integrated use of CAD facilities among all ship construction facilities
- o Study of material handling techniques to improve operations in dry dock facilities
- o Develop and implement computer-controlled frame bender for ships frames
- o Develop and install 3D system with interactive circuit design features to improve productivity in LSI chip production

U.S. Navy (cont'd)

- o Develop a numerically controlled sheet metal fabrication cell
- o Develop a computer-controlled optical measurement system to improve efficiency in measurement of propeller components
- o Develop automated robotic welding system to improve quality of propeller component welding operations
- o Develop an optical-controlled laser cutting and welding process that will improve quality and reduce fixturing requirements
- o Develop a flexible manufacturing system to efficiently handle and fabricate large steel and aluminum structural shapes
- o Develop a vision-assisted robotic arc welding system
- o Develop a CNC-controlled machine to fabricate pipe joints with complex geometry
- o Develop a robot-assisted surface painting and preparation system
- o Develop a realtime, closed-loop controlled robotic welding system to improve weld quality and efficiency
- o Develop an automated propeller balancing system that will correlate "out of balance" data with geometry data to indicate corrective operations
- o Design 3-D vision system to control robotic welding operations
- o Identify productivity enhancements that can be implemented at the Newport News Shipbuilding Facility
- o Develop a central CAD-driven design and manufacturing data base that will contain all information necessary to manufacture parts
- o Develop an active 3-D robotic vision system to control welding operations
- o Develop an automated technical information system for managing the storage and retrieval of engineering and manufacturing information for spare parts
- o Apply the latest CAD/CAM technologies in implementing the fabrication and assembly of Microwave Integrated Circuit (MIC) modules
- o Develop computer-aided manufacturing techniques for the construction of a high-power, high-gain surface radar system
- o Design and implement a fully automated PCB assembly line (CCAPS)
- o Design a generic, flexible manufacturing system for military microelectronic assemblies

National Science Foundation

- o Study of Computer-Aided Manufacturing for Polymer processing
- o Study concerning the combined use of tactile sensing and computer graphics to control automated design and fabrication of molds for plastic processing

National Bureau of Standards

- o Advanced Manufacturing Research Facility in Gaithersberg, MA
- o Develop technical support for realtime control of complex, sensory-interactive robots

NASA

- o Create a Software Engineering Laboratory to study advanced software engineering techniques to improve NASA efficiency in the areas of mathematical modeling, configuration management, systems reliability and life cycle costs

DOE

- o Study of information systems to provide services in the area of computer-aided instruction, expert systems, simulation, configuration management and quality assurance (w/Navy)
- o Study of data base management systems for configuration management, engineering and expert systems (w/Army)
- o Study to perform a comprehensive analysis of engineering change proposals and technical data package management for a class of amphibious vehicles (w/USMC)
- o Study of engineering change proposal and technical data package management for the Advanced Tactical Airborne Protection System (ATAPS) (w/Navy)
- o Study of Reliability Centered Maintenance (RCM) and Configuration Management programs for U.S.M.C. depots
- o Provision of data base and configuration management systems support to the U.S. Navy's David Taylor Naval Ship Research and Development Center (DTNSRDC)
- o Provide computer system support to maintain production engineering and configuration managements subsystem elements of the U.S. Navy's Computerized Air-Launched Missile Management Systems
- o Provide minicomputer and supercomputer support to the User Service Center of the Los Alamos National Laboratory for CAD/CAM applications in the area of "reversed field punch upgrades"

Veteran's Administration

- Perform research into computer graphics (CAD) and computer numerically controlled machining (CAM) of external human joint assemblies
- Design CAD and CAM techniques to automatically design and fabricate lower extremity prosthetic sockets
- Study the use of CAD/CAE/CAM systems in implementing a Computer-Aided Prosthesis Alignment System

CIM Programs at Nongovernment Organizations

In the process of investigating the nature and status of current research and development efforts pertaining to CIM technologies, Arthur Andersen & Co. contacted a number of professional organizations in business and academia. Most of them either hold distinguished reputations as leaders in implementing CIM technology or are presently establishing such credentials. Among these organizations are several leading universities that have invested substantial resources into research and promotion of CIM.

CIM Programs at Selected Universities

Our research efforts focused on academic institutions that have been identified as major contributors to the advancement of CIM technology. They have been honored for their programs by LEAD awards presented by CASA/SME, and/or are frequently referenced in technical literature describing their achievements. Some examples of current CIM development at these universities are:

- Purdue University has launched the $10 million federally funded Engineering Research Center for Intelligent Manufacturing Systems (ERC) to supplement its four-year-old CIM R&D program, the Computer Integrated Design & Manufacturing Automation Center (CIDMAC). CIDMAC is a consortium of eight companies and the University, and currently contends with a $4 million annual budget, as well as $5 million in equipment, mostly donated by its eight corporate affiliates.

  There are presently over 60 projects underway in specialized areas of CIM technology. The breakdown is approximately:

  - 30% in development of vision-based systems for use in intelligent inspection and robotic assembly processes.
  - 16% in automated material handling (AMH) technology, primarily automated guided vehicles (AGVs) and automated storage and retrieval systems (AS/RS).
  - 16% in computer-integrated manufacturing (CAM) technology, primarily CNC/DNC machine accuracy, rapid recalibration of machine tools and robot motion control improvements.

Accordingly, flexible assembly and machining systems (FAS/FMS) receive a high priority, along with CAD interfaces with CAM and various process planning technologies. The most recent development is the establishment of an FMS cell complete with robotic equipment and artificial intelligence (AI) support. The FMS cell is to be exhibited to the public and used for training purposes.

- Tulane University has established a Programmable Automation Laboratory that includes the latest advances in robotic equipment. A strong effort is currently underway in areas of robotic visualization for welding and assembly applications. The research focuses on the use of fiber optic technology to improve the effectiveness of stereoscopic vision techniques for analyzing shapes in assembly operations.

- Brigham Young University is a leader in software development for multiple decision support and robotic simulation applications. The University has established two CIM research centers--the CAM Software Research Laboratory and the Systems Automation Laboratories for Robotics, Design and Manufacturing. It has also developed a number of successful packages that are commercially available, including DCLASS, a group technology support software application, and SMART, a simulation program most effective in CAM robotic environments. Additional research is being undertaken in time/motion studies, cost effects of product redesign to enable robotic assembly operations, interface of graphics to NC machine tools and the effective utilization of data generated by vision systems.

- Ohio State University, along with Brigham Young, Carnegie-Mellon, Lehigh and the University of Illinois, have received a $10 million government grant to establish a "center of excellence" in manufacturing R&D. The program agenda includes CAD/CAM integration and research into most areas of CIM technology.

- Oklahoma State University at Okmulgee is a pioneer in CIM education, particularly CAD/CAM and CNC machine systems. It has established the Noble Center for Advancing Technology, which includes several CIM laboratories and simulated factory environments. The University enjoys considerable support from corporations in the surrounding states, which are large employers of the manufacturing graduates and trainees educated at the CIM Center.

- Lehigh University has a strong emphasis on CAD/CAM and manufacturing systems research. Among its many facilities is the Center for Design and Manufacturing Innovation (CDMI), which stimulates research, facilitates technology transfer, promotes the use of interactive graphics in engineering education and develops competent CIM professionals. Lehigh is a recipient of the LEAD award in recognition of its graduate programs in areas of CIM.

- University of Florida has established a sophisticated network of laboratories for CIM instruction and research. Among them is a CAD/CAM support facility equipped with computer hardware and design software donated by IBM: the Interactive Graphics Laboratory and the Computer Graphics Research Laboratory, which handles realtime digital video synthesis and animation as well as robotic simulation.

- University of Michigan at Dearborn is establishing the CAD/CAM and Robotics Laboratory with help from the Ford Motor Company and other industrial partners. It will house computers, CNC machines, robots and laser/welding equipment to be used in applied research and development for industry.

- Arizona State University has established the Center for Automated Engineering and Robotics within its Engineering Research Center. It is considered a national "test bed" for manufacturing operations and has an impressive environment of IBM and DEC computers, along with other hardware supplied by different vendors. Accordingly, both MAP and Ethernet communication standards are utilized in research and testing processes. The center was recently granted substantial hardware and software resources by IBM Corporation, including state-of-the-art design packages such as CADAM and CATIA.

Similar programs can be found at many other universities throughout the country.

The common strategic objectives of surveyed universities focus on developing state-of-the-art facilities that can provide adequate educational opportunities for future CIM professionals. Most of the surveyed institutions exhibit strengths in specialized areas of CIM technology, with several institutions having developed strong programs in systems integration. However, with the exception of Purdue, most universities support only limited numbers of graduate students and research engineers, thus failing to alleviate the current shortage of well-trained CIM professionals. This is the case even though the numbers of applicants greatly exceed available openings at the universities.

Potential limitations to CIM research and education are caused by insufficient funding and the shortage of qualified instructors. Consequently, the universities have relied heavily on corporate contributions and joint ventures with industry to procure the resources necessary to pursue CIM programs. This has often led to an emphasis on developing CIM products and related software for commercial distribution, rather than scientific advancement.

At the same time, however, industrial organizations are benefiting substantially from CIM programs undertaken by the universities, particularly those companies that have sponsored the programs and underwritten much of the costs of research. There is notable collaboration between university laboratories engaged in CIM research and commercial and government organizations desiring to benefit directly from the research. To the extent that this trend continues and financial support from government agencies increases, the outlook for future advancements in CIM technologies and the benefits generated by their application is encouragingly optimistic.

CIM Programs at Commercial Enterprises

The research and development of CIM technologies extends considerably beyond the conceptualization of potential applications and the various university-sponsored efforts. Commercial enterprises are increasingly devoting large amounts of capital resources into the enhancement of factory automation technologies and the realization of practical CIM environments.

Arthur Andersen & Co. has been following the progress of CIM developments at a number of companies that are recognized as leaders in the areas of factory automation. Some of them are LEAD award winners and practically all have been featured in industry publications or honored at CIM symposiums.

- At Cone Drive Operations of Ex-Cell-O Corporation, Traverse City, Michigan, successful CIM technology implementation was made possible by the development of innovative software to integrate the business planning system, CAD/CAM system and shop floor operations. The system is to design a part, create a CAD/CAM model, generate source codes for N/C machining, transfer information to machine tools and manufacture the part automatically in minutes. The facility manufactures worm gear speed reducers, gear sets and gear motors.

- At General Electric Company, Steam-Turbine Generator Operations, Schenectady, New York, the CIM system has fully integrated marketing, engineering, manufacturing and finance functions at the small parts shop, which annually produces some 325,000 parts in thousands of different configurations. The parts are used in turbine-generators that are custom manufactured to meet specific requirements of electric utility and industrial customers.

- At General Electric's distribution plant in Louisville, Kentucky, practically the entire production process has been automated. Parts manufacture, unit assembly and warehousing are controlled and tracked by programmable controllers linked to a mainframe computer running custom software. Extensive use is made of optical data collection devices, such as bar-code scanners and vision systems.

- At AT&T Technologies, Inc., Printed Wiring Board Facility, Richmond, Virginia, a fully integrated manufacturing control system is used in the automated production of printed wiring boards. The computerized monitoring system permits close control of complex manufacturing operations and has brought significant savings in cost and production time.

- At Ingersoll Milling Machine Company, Rockford, Illinois, the special machinery builder's CIM installation was designed to cover all production and business functions related to the same common data base. CAD/CAM, bill of material, production control, inventory control and accounting system functions are controlled by a single computer-based manufacturing system.

- At Deere & Company, Waterloo Tractor Works, Waterloo, Iowa, computer-coordinated operations include material receiving, storage, retrieval and delivery throughout the factory, sheet metal fabrication, machining, wheel manufacturing, painting, assembly, and inspection of the tractors and cabs. In addition, purchasing, production control, industrial engineering, accounting and business systems are part of a computer-integrated business system.

- At General Motors Corporation plants in Hammtramck and Saginaw, Michigan, MAP is being installed to link all manufacturing cells. A central factory control system is planned to schedule changeovers from one type of automobile design to another, downloading the new manufacturing programs automatically into the cell computers. All information will be stored and transmitted electronically, thus eliminating most paperwork. The corporation currently uses over 40,000 robots, programmable controllers and NC machines, including 500 vision-based CAI systems, and plans to invest $40 billion to bring the total to 250,000 units, including 44,000 vision systems and 14,000 robots within five years.

- At Chrysler Corporation, based in Warren, Michigan, 550 workstations with over 3,000 users at 18 "design and development" centers share a large engineering data base on a network connected to 27 mainframe computers. The system is currently being extended into manufacturing, enabling the electronic transfer of information from design through production via a shared data base.

- At Allen-Bradley Company, Milwaukee, Wisconsin, the new electrical contactor factory is among the most automated facilities in the world. It also provides the opportunity to demonstrate the company's own factory automation equipment, programmable logic controllers (PLCs). The most prominent feature of the CIM facility is its 50-machine, $15 million flexible assembly complex, which reads production requirements from bar codes and produces motor starters in 125 different configurations at the rate of 600 an hour. The CIM network is comprised of a mainframe computer, area controller, cell controller, 26 PLCs, and a variety of sensing and control devices at the machine level.

In contrast to the fragmented/incremental approach to CIM research and development exhibited by many organizations in the past, a new strategy is being promoted by leading corporations. That strategy is centered on the integration of CIM technologies using advanced manufacturing planning and control systems as a foundation.

In addition to the examples described above, large defense contractors like Lockheed, TRW and LTV, as well as General Motors Corporation's famous Saturn Division, are presently developing state-of-the-art CIM facilities from the "ground up." This illustrates the increasing commitment to CIM in the strategic plans of future-minded organizations.

U.S. ARMY MATERIEL COMMAND

CAD/CAM DEVELOPMENT STUDY

TECHNOLOGY AREAS OF CONCENTRATION

		FACTORY AUTOMATION					PRODUCT/PROCESS ENGINEERING							MANUFACTURING PLANNING/CONTROL						INFORMATION PROCESS SUPPORT ARCHITECTURE				
ORGANIZATION	TOTAL PROJECTS	AMH	Factory Commun.	CAI	FAS/ FMS	Advanced Data Coll.	CAD	CAE	GT	AI	CAM	TDP	MRPII**	JIT	SPC	Simulation	Maint. Manage't	Quality Manage't	Hardware	Software	Integration	Communications
U.S. ARMY	42	4	3	8	8	2	7	2	3	4	18	3	5	0	6	3	4	7	5	9	3	5
U.S. NAVY	92	3	9	6	7	6	8	1	1	2	20	8	2	0	0	0	0	0	0	0	0	
U.S. AIR FORCE (See note ***)	93							MED		MED	HIGH	MED						HIGH			HIGH	
OTHER GOVERNMENT AGENCIES (DOE, NASA, VA, NBS, NSF)	16	0	0	0	0	0	5	1	0	0	6	2	0	0	0	0	1	0	1	4	0	0

** OPT, etc.

*** Detailed breakdown not available due to time and resource limitations

APPENDIX C - INTERVIEW SUMMARIES

INTERVIEW NOTES

Date: 10/22/86 Time: 10:00 a.m.

Organization: U.S. Army Depot Systems Command

Representative: Michael Ahearn

Notes:

1. CAD/CAM Projects (Internal)

   - o No overall strategy for CIM at DESCOM, or U.S. Army as a whole.
   - o Major automated PCB assembly program at Sacramento Depot.
   - o Currently there are four different CAD systems and numerous nonintegrated NC machines at the Chambersburg facility.
   - o Industrial Modernization Incentive Program (IMIP) has initiated a few projects in DESCOM but has not been very effective overall.

2. CAD/CAM Projects (External)

   - o Not aware of any major external CAD/CAM programs

3. CIM Barriers

   - o Funds are being spent inefficiently.
   - o Current organization structure is too rigid. New technology does not have an effect on the organization.
   - o MIS-related functions have approval responsibilities for factory computer systems, but they do not have adequate knowledge of factory system requirements.

4. Key Features of Army's CIM Strategy (Needs)

   - o Organization structure must change to enhance information sharing.
   - o A clear, coordinated goal must be established to direct U.S. Army CIM efforts.
   - o Any directing effort must be able to enforce its mandates.
   - o The Army should foster standards for integration, especially in the area of control systems for CNC machining.

- o Mainframe computers for business systems lack information interchange capabilities and should be upgraded.

5. Miscellaneous (Benefits, Contacts, etc.)

CIM Benefits

- o Reduced overhaul costs
- o Level loading of production resources
- o Increased productivity
- o Lower scrap/higher product quality

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/14/86 Time: 9:00 a.m.

Organization: AMC/Information Management Directorate/Advanced Computing Branch

Representatives: Daniel Epps - Branch Chief
Arnelle Brown - Action Officer

Notes:

1. CAD/CAM Projects/Strategies (Internal)

   - o Current 3-tiered plan for Information Processing support within AMC:
     - Tier 1 - Large-scale computers (30XX mainframes, not super-computers, MVS/XA, vector processing)
     - Tier 2 - Medium-scale computers (370 series, DEC/VAX, UNIX, VMS)
     - Tier 3 - Office automation (PCs, MS/DOS)
   - o VENUS teleconferencing project
   - o BRL efforts in hyper-channel communication and supercomputing
   - o Alternative of networked minicomputers vs. supercomputers for S/E computing

2. CAD/CAM Projects (External)

   - o A current study is being undertaken with MIT and Battelle Labs to determine integration possibilities for AI, CAD and CAE.
   - o CALS project to foster networked communication among DoD engineering/manufacturing sites.

3. CIM Barriers

   - o Overly complex procurement procedures
   - o Need to allow for creative flexibility while maintaining some standards for equipment purchase

4. Key Features of Army's CIM Strategy (Needs)

   - o Standardized communication network
   - o Encryption/security requirements for data passing over a network

5. Miscellaneous

- Main purpose of IMD/ACB is to expedite 70-1, 25-5 and 18-1 processes to acquire CAD and supercomputing reservices.

- For more information on graphics exchange on supercomputing at BRL contact Bob Black at Defense Research Labs (see S. McGlone).

- For more information on BRL/TACOM efforts on supercomputers to do CAD and CAE, see Mr. Washburn (TACOM).

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/14/86 Time: 10:00 a.m.

Organization: AMC HQ

Representatives: Dick Barnett
John Holvoet

Notes:

1. CAD/CAM Projects (Internal)

   - o DSREDS - Automated technical data repository for storage of graphic (digitized, non-CAD) data. Can manipulate 2-D IGES only.
   - o 600S Project - $700 million effort for automated publishing, data storage and transfer. (Currently canceled.)
   - o DESCOM has many small AMT projects that are not cataloged

2. CAD/CAM Projects (External)

   - o U.S. Navy's CAD systems procurement project
   - o New standards for graphics exchange
     - IGES Version 3.0 - Vector Data
     - CCITT Version 4.0 - Raster Data
   - o ADODIS project sponsored by the DoD
   - o USAF ATF Data Integration Project.
   - o USAF B-1 Bomber project mandated electronic format for creation, modification and transfer of design data

3. CIM Barriers

   - o Current lack of a digital information exchange standard.
   - o Problem of how to deal with the data accuracy "guarantee" in the typical designer-to-producer chain.
   - o Two percent limit on AIF funds for AMT investment is not adequate.
   - o Capital expenditure justification procedures make it difficult to purchase technologies that do not pay back within one year.
   - o Independent purchase of a variety of nonintegrated equipment.

- o Current short-term cost-based procedures for selecting systems contractors and the number of contractors for a project.

- o Portions of DoD100 make it difficult to comply with data integration standards.

4. Key Features of Army's CIM Strategy (Needs)

   - o U.S. Army should take an active role in promoting an information exchange standard.

   - o Strategy should have goal.

   - o Standards for equipment and communications are needed to ensure transportability of information.

   - o Improved configuration management process that will facilitate testing of complex weapons systems.

5. Miscellaneous (Benefits, Contacts, etc.)

   - o Additional information on the Navy's CAD project, contact Russ Shorey at Office of the Secretary of Defense/Weapon Systems Branch.

   - o Additional information on the USAF Data Integration/Transfer subproject for the Advanced Tactical Fighter program contact Roy Bohanon at Wright-Patterson Air Force Base.

   - o Fred Michel is a good source of information for data integration and contractor-based problems.

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/14/86 Time: 2:00 p.m.

Organization: U.S. Army Laboratory Command

Representatives: Stan Alster
Bob Rosen
Malcolm Mackenzie
Cynthia Tootle

Notes:

1. CAD/CAM Projects (Internal)

   - o EDTL (Electronic Devices Testing Laboratory) has several projects for CAD/CAM in relation to VHSIC (Very High Speed Integrated Circuit) design and manufacture.
   - o BRL is performing high-level research with CAD and supercomputers.
   - o Night Vision Labs are doing things with CAD and CAI.

2. CAD/CAM Projects (External)

   - o AMRF project at NBS
   - o Reverse engineering projects at:
     - EDTL
     - Defense Logistics Agency (DLA)
   - o Army Research Office is North Carolina

3. CIM Barriers

   - o Lack of funds caused by cancellation of MMT program.
   - o Current strategy by Army is disjointed--many programs going in different directions.
   - o Knowledge developed on one project does not get transmitted to other projects.
   - o Government specs for systems are outdated in relation to current manufacturing technology.

4. Key Features of Army's CIM Strategy (Needs)

   - o Since purchasing turnkey, CAD systems is a major trend. Standards for equipment purchase are essential.

- o Technical history data for a product or system should be maintained in electronic format from design inception through delivery and testing.

- o Needs a central, agreed-upon goal.

- o A centralized training strategy is needed to enhance CAD/CAM effectiveness.

- o Portability (through data exchange standards) is a key element.

5. Miscellaneous

   - o Contact at BRL is Paul Weinacht (301) 278-6956.

   - o Randy Reitmeyer at EDTL and Bob Cooper at DLA are good contacts for CAD/CAM in reverse engineering.

Benefits of CIM

- o Productivity increase
- o Better quality
- o Enhanced knowledge capture
- o Enhanced manufacturability through use of design rules

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/14/86 Time: 2:00 p.m.

Organization: U.S. Navy Sea Systems Command

Representatives: Dale Christensen
Marlene Fox-McIntyre

Notes:

1. CAD/CAM Projects (Internal)

   - o CAEDOS project involved acquisition of CAD systems for Navy labs only. Current terminals installed are 400 color, 100 mono.

   - o NAVSEA assigned as lead for CAD/CAM in Navy. NICAM2 (also known as NCGA - Navy Computer Graphics Acquisition) contract expected to be out for bid within next 2-4 months. Major emphasis is buying digital information. Primary emphasis on CAD, but some CAM is included. Will use actual weapons system to define/debug strategies (SSN21 & DDG51).

   - o Current emphasis in Navy is to perform 30%-50% of design, then ship out remainder to detail design contractors.

   - o Navy has long-term commitment to IGES and PDES, UNIX and IEEE802.3 broadband networks. NICAM2 will incorporate above with workstation-based approach.

2. CAD/CAM Projects (External)

3. CIM Barriers

   - o Navy approach to dealing with IGES problems, data "guarantee" problem, etc., is to start with something and debug as they proceed, not wait until 100% perfect.

4. Key Features of Army's CIM Strategy (Needs)

   - o Use experience gained in previous contracts/projects as basis for new projects.

5. Miscellaneous (Contacts, Benefits)

   - o Contacts for AI - Dr. Pat Hartman
     Robotics - W.P. Butler
     NICAM2 PM is Capt. Joe Callahan

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/15/86 Time: 9:00 a.m.

Organization: U.S. Army Communications-Electronics Command

Representatives: Dr. Dirk Klose - Director of CALS (Computer-Aided Logistics System)

Notes:

1. CAD/CAM Projects (Internal)

   o CALS Mission (contractor proposal to be released 10/27/86):

   - To establish data integration standards for CAD/CAM (i.e., transfer process control information)

   - To develop a neutral language for storage of vector graphics

   - The major objective is to design producability, reliability and maintainability into major weapons systems

   - Major deliverable will be delivery of electronic data base of information

2. CAD/CAM Projects (External) (text, graphics, process control)

   o BDM (Contractor at BRL, Aberdeen, MA) - Currently developing CAD systems with FEM & FEA capability, along with ability to "simulate" the physical reaction of a projectile upon impact.

   o ETDL - Currently developing CAD systems for design and production of printed circuit boards.

   o DESCOM - Identified as a major user of CAD systems.

   o AMSRC (Acquisition Management System Review Committee) - Currently reviewing CAD/CAM technologies.

   o CALS may have some interface with the Navy's NALCOMIS project.

3. CIM Barriers

   o Government agencies only "check" data. Exchange and validation of data must be enhanced as government currently checks only 10% of data.

   o The current large number of policies, procedures and directives.

   o Determining what type of information to produce from contractors.

4. Key Features of Army's CIM Strategy (Needs)

   - o The ability to capture technical history for major weapons system development.
   - o The single, consistent policy for how information is produced, used and transmitted to different organizations.
   - o The U.S. Army should attempt to foster consistent standards among contractors/industry for electronic exchange of data.

5. Miscellaneous

   - o CALS will attempt to develop software tools to facilitate transfer of data to integrate design, production and maintenance functions.

INTERVIEWING TRIP TO WASHINGTON, D.C., AND FT. MONMOUTH, NJ

INTERVIEW NOTES

Date: 10/15/86 Time: 1:00 p.m.

Organization: U.S. Army Research Development and Engineering Command (ARDEC)

Representatives: Wayne Lunger
Geza Pap
Michael Stroukoff

Notes:

1. CAD/CAM Projects (Internal)

   - o A CIE (Computer-Integrated Engineering) effort is underway at ARDEC to standardize hardware and communication protocols for CAD, CAE in that location. It is a sub-effort of AMSRC.
   - o The light howitzer program is working with CAD/CAM and electronic TDP. The CIE program may set some standards for their equipment acquisition.
   - o Current CAD systems are Computervision-based and communicate in a UNIX, broadband cable environment. By end of next year, they will have 3,000+ computers and 40+ NC machines.

2. CAD/CAM Projects (External)

   - o ASMRC CAD/CAM Steering Group
   - o NDT, SPC and expert systems have been informally emphasized at ARDEC

3. CIM Barriers

   - o Numerous and uncoordinated strategies for systems integration

4. Key Features of Army's CIM Strategy (Needs)

   - o Development of a neutral file format for Technical Data Package management.
   - o Enforceability through education or mandates.
   - o Implementation of cost justification techniques.
   - o Means to develop/keep competent personnel to oversee/execute strategy.

- o References in contracts for TDP requirements should be more generic and give contractors the ability to furnish more information.

- o Need to encourage contractors to use CIM by giving them some benefit (i.e., reduced inspection points).

5. Miscellaneous (Benefits, Contacts, etc.)

CIM Benefits

- o Reduced product development and maintenance costs
- o Standardized cost justification techniques
- o Improved organizational efficiency

INTERVIEW NOTES

Date: 11/25/86 Time: 2:00 p.m.

Organization: U.S. Army Management Engineering Training Activity
Attn: AMXOM-SE
Rock Island, Illinois 61299

Representative: Alvin K. Takemoto, Management Enginering Consultant

1. Current CIM Educational Programs

   - o 12 ongoing or planned CIM courses within AMETA
   - o Currently over 50 manufacturing-related courses
   - o Some courses mandated for some job classifications
   - o Other courses available from external institutions such as
     - CASA/SME
     - Defense Interim Training Center
     - Defense Systems Management College
     - Air Force Institute of Technology
     - Naval Resources Management Education Center

     and are listed in the Defense Management Education and Training Catalog
   - o Most courses given by AMETA are taught by AMETA employees, but some employ outside experts

2. Barriers for Effective CIM Education

   - o Lack of knowledge of educational resources available
   - o Cost implications
   - o Lack of knowledge of education benefits
   - o Insufficient funding (availability for students always less than demand)

3. Benefits of CIM Education

   - o Improved AMC productivity
   - o Decreased CIM implementation risk
   - o Elimination of "fear of unknown" that hinders use of advanced technology
   - o Enhanced decision-making capability for managers

INTERVIEW NOTES

Date: 10/21/86 Time: 10:30 a.m.

Interview with: Roy Oliver
Division Chief/Production Engr. Div.
Corpus Christi Army Depot
Attn: SDSCC - MP
Corpus Christi, TX 78419
(512) 939-3979

1. Current CAD/CAM Projects and Strategies (Internal)

   - o Only aviation repair depot - early user of CAD/CAM systems (first system around 1970).
   - o Current CAD/CAM system is used for tool design.
     - 8-10 workstations during facility layout and NC programming
     - 20-25 NC and CNC machines
   - o A project is planned to expand CAD/CAM workstations in engineering, manufacturing and facilities management areas. Acquisition will involve new computer and additional (20+) workstations.
   - o Not aware of overall CIM strategy.
   - o DESCOM did a study in the late 1970s to justify procurement of CAD/CAM technology.
   - o IBEA (Steve McGlone) have current CAD/CAM guidance responsibility.

2. CAD/CAM Projects (External)

3. CIM Barriers

   - o Justification process is very difficult (procedures are complex and time consuming).
   - o Knowledge of new technology and related CIM project efforts is difficult to obtain.
   - o Lack of funding.

4. Key Features of Army's CIM Strategy (Needs)

   - o Management of engineering changes would be improved by the electronic transfer of product data to/from contractors.
   - o Centralized service for CIM education funding information and application assistance should be created.

- Additional contacts at Corpus Christi AD:
  - Frank Gross, x3561
  - E. V. Garcia, x3434

CIM Benefits

- Reduced labor costs.
- Required to accomplish depot mission.
- CAD/Graphics are also useful as a management tool (i.e., preparing briefings).

INTERVIEW NOTES

Date: 10/22/86 Time: 1:00 p.m.

Interview with: Duane George
CAD/CAM Systems Manager
Sacramento Army Depot
Sacramento, California
(916) 388-2830

1. CAD/CAM Projects (Internal)

   - o Automatic test fixtures and equipment (TLQ17A).
   - o Have MAP/TOP capabilities, and IDEF and IGES (latter not popular).
   - o Currently using Gerber CAD system; installing Intergraph system with 22 workstations in January.
   - o Automated printed circuit board (PCB) design system, using vision systems, group technology (GT) and automated process planning (CAPP).

2. CAD/CAM Projects (External)

   - o Only informally familiar with CAD/CAM development at other U.S. Army installations; knows more about Navy's CAD/CAM progress through personal contacts.
   - o Not aware of any Army-wide CIM strategy or any governing body/ organization devoted to promotion of CIM.
   - o Much enthusiasm and support for CAD/CAM among Depot personnel.

3. CIM Barriers

   - o Severe funding problems; have to use last year's budget for CAD/CAM because this year's budget is $0.
   - o CAD/CAM procurement problems due to excessive bureaucracy, red tape and approval delays.
   - o No defined strategy for CIM realization, nor any strong central authority that promotes CIM.
   - o Insufficient knowledge of CAD/CAM across Army installations; have to contend with "pockets of CAD/CAM-knowledgeable personnel."

4. Key Features of Army's CIM Strategy (Needs)

   - o More use of group technology data bases.

- o Standardization of equipment across Army installations.
- o Use of stand-alone versus host-based workstations.
- o Remove IGES; it is too big and newest version too complex for existing equipment.
- o Closer cooperation with corporations, like the Navy has.

5. Miscellaneous (Benefits, Contacts, etc.)

- o Al Hollander at (916) 388-3417 (on vacation when this interview was conducted).
- o Jim Sellner at (916) 388-2830; Chief of Project Design and Development (not available when this interview was conducted).

Benefits

- o Reduced operating costs
- o Improved productivity
- o Better quality

INTERVIEW NOTES

Date: 10/24/86

Organization: Martin Marietta Energy Systems Division
Y-12 Plant
Oak Ridge, Tennessee

Individual: Michael Cuddy - Director of CIM

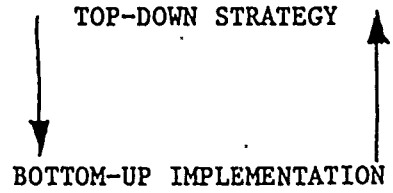
A. CIM = Factory Management and Information Systems (center of wheel)
Computer Network Systems (between FM&IS and outer ring)
CAD and Engineering (outer ring)
CAM (outer ring)
Program Management (outer ring)

B. Project Economics (expenditures): $ 50M since 1982

$140M through 1992 - where breakeven occurs

C. Started with "CIM Business Hierarchy"

DOE CIM Objectives
Y-12 Mission and Objectives
CIM Mission and Objectives
CIM Architecture
Functional Goals
Projects



D. Product Definition Data Flow

- Electronic data flow between 11 DOE design and manufacturing sites around U.S.
- Uses IGES and DOEDEF (Dept. of Energy add-on to IGES) - MMES (Martin Marietta Energy Systems) performs translation on a VAX cluster for all supported sites.
- Currently working at 5 sites, each with different CAD/CAM systems (MMES uses ANVIL 4000).

E. CIM viewed as a catalyst for SYSTEMS CHANGE (i.e., human, functions, organization and technical) vs. strictly a TASK AUTOMATION exercise.

F. Reactions/implications for Army CAD/CAM strategy

1. Army needs to establish CIM in the context of their overall weapons systems design and manufacturing strategy.
2. Army should study effectiveness of IGES/DOEDEF as potential standard for electronic product design data interchange. (IT WORKS!!)

3. Army should consider Martin Marietta's projected investment ($140M over 10 years) with respect to their "2% solution" idea to determine adequacy and feasibility of effectively "incentivizing" private contractors to adopt CIM. Simply put, applying 2% of any contract award to CIM technology development is not adequate to coax substantial CIM investments from contractors.

4. MMES appears to put Factory Management at the heart of their CIM system. This seems to suggest its relative importance compared to automation and process-related technologies. The Army should recognize this in their "incentivizing," and in their weapon systems acquisitions.

CONGRESSIONAL TESTIMONY (HAC)

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HEARING DATE	TRANSCRIPT PAGE NO.	LINE NO.	INSERT NO.
4/23/86	98		4

CAD/CAM TECHNOLOGY

QUESTION: Dr. Wade, do you require each Service to have a well thought out and planned CAD/CAM acquisition strategy, or will you allow interim requirements contracts to proliferate?

ANSWER: Yes, we will require each Service to develop and implement a well thought out and planned acquisition strategy for systems that employ specific CAD/CAM capabilities. "CAD/CAM" is among the many advanced technologies utilized by DoD to more efficiently design, produce, and support new weapon systems. However, CAD/CAM is not a single, isolated technology, but rather an umbrella term used to describe application of state-of-the-art computer-based technology to a broad class of problems related to design and manufacturing functions. In the context of the questions asked, we understand the term to refer to computer aided design and engineering applications, rather than the full scope of manufacturing and production. DoD does not and cannot manage "CAD/CAM technology" per se. DoD will coordinate the application of these technologies for selected high payoff functions such as logistics, principally by defining the interface standards for ensuring system compatibility and integration. Moreover, because CAD/CAM is not a single technology, but rather a family of interrelated technologies, there will be tailored acquisition of CAD/CAM capabilities by functional user organizations within each Service. The basis for being able to implement this strategy successfully is the program DoD has established with the National Bureau of Standards to develop the technical standards for interfacing and integrating the hardware and software acquired by each functional user community. These national standards will be adopted and implemented by DoD, computer manufacturers, major defense contractors, and their suppliers.

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CAD/CAM TECHNOLOGY

Question: How much is budgeted by Service and appropriation (including industrial funds) in each fiscal year 1985 to 1991 for the acquisition and O&M of CAD/CAM technology?

Answer: Because funding for acquisition and support of CAD/CAM technology is not identified as a separate budget line item by any Service, the following information is still incomplete. Efforts are underway to identify additional requirements, and to further define tne scope of currently planned acquisitions. Additional information will be available by September 30, 1986.

(Dollars in millions)

	FY-85	FY-86	FY-87	FY-88	FY-89	FY-90	FY-91
Army							
RDT&E	7.3	6.3	3.9				
Civ Works		0.7	26.6	5.2	2.8	1.2	0.7
Navy							
NIF	12.8	15.2	9.8				
O&M	1.9	2.3	2.5				
RDT&E	2.7	1.9	2.1				
MILCON	2.0	1.9	2.1				
Air Force							
3600	2.3	5.1	7.8	7.5	10.0	11.2	7.8

Army RDT&E includes programs specifically targeted to develop new applications involving CAD/CAM technology, funded under the Manufacturing Methods and Technology (MMT) program. Funding for FY-85 through FY-87 encompasses 12, 10, and 6 MMT projects respectively that are clearly identifiable as CAD/CAM installations. Additionally, during this same period, 37 of 157 FY-85 MMT projects, 32 of 119 FY-86 MMT projects, and 14 of 46 FY-87 MMT projects are CAD/CAM related in some way, but not primarily CAD/CAM technology. Requirements beyond FY-87 have not been identified.

Army Civil Works covers acquisition of multiple CAD systems by the Corps of Engineers under the Civil Works Revolving Fund. Data for FY-85 and FY-86 ($690,000) is combined under FY-86. Data for FY-87 through FY-91 ($36,497,000) cover validated and approved requirements, for which funding has been programmed. The contract under which these systems will be acquired is scheduled for award approximately October 1, 1986, and will contain options that could allow total CAD acquisition during this period to reach $120M. However,

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requirements for CAD systems above the currently programmed amount have not been identified; each system must be individually validated and approved, and must compete for funding against other requirements.

The preponderance of Navy funds are in support of identified requirements for the current Computer-Aided Engineering and Documentation System (CAEDOS) contract. Outyear funding levels are not yet specifically approved. However, it is anticipated that FY 1988 and later year funding will remain at approximately the same levels for the forseeable future. These funds support application system development, maintenance, modification, etc. MILCON funds support architectural and engineering work in the facilities areas, the RDT&E funds support work in the ship design arena, and O&M funds supporting existing CAEDOS equipment outside of the NIF environment. Navy NIF supports CAEDOS hardware, software, and services provided to shipyards, air rework facilities, ordnance stations, etc.

Navy is evaluating emerging requirements, which will be supported by the Navy Graphics CAD/CAM Acquisition (NGCA). There is still no approved plan, nor have any funds been budgeted to support these requirements. As previously reported (Question 98-7d), funding requirements will not be available until System Decision Papers (SDP) I/II are completed at the end of FY-86. Additional resources will be sought after a plan is approved; it is anticipated that this will occur during the POM-89 cycle. The level of funding supported will be dictated by overall Navy requirements and priorities across the board. Navy representatives are prepared to brief Congressional personnel at their convenience on this program, its scope, and future direction.

Air Force 3600 includes CAD systems from all sources acquired, or validated and approved for acquisition by Air Force Systems Command (AFSC). AFSC's engineering and scientific work station contract, which is presently in source selection and is scheduled for award by October 1, 1986, although not primarily a CAD contract, will provide some limited CAD capability for AFSC and other Air Force major subordinate commands. Air Force CAD/CAM requirements against this and other appropriations are presently being surveyed, and will be available in September 1986.

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CAD/CAM TECHNOLOGY

QUESTION: Are all Service programs fully funded?

ANSWER: Service programs are not fully defined at this time. Funding requirements will follow from the development of implementation and acquisition strategies by each functional user community.

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CAD/CAM TECHNOLOGY

QUESTION: How does budgeted funding compare to the requirement?

ANSWER: Specific shortfalls are not yet fully identified. However, in the case of the Navy Industrial Funds, the preponderance of CAD/CAM requirements will be satisfied from within available funds.

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CAD/CAM TECHNOLOGY

QUESTION: What OSD oversight, particularly through the Major Automated Information System Review Council, is planned for Service CAD/CAM "architectures," strategic plans, and specific acquisition plans?

---What involvement have you had to date, Dr. Wade?

ANSWER: There currently are no scheduled MAISRC's planned for CAD/CAM. The Services are establishing their Computer Aided Logistic Support (CALS) organizations, implementation plans, and CAD/CAM acquisition strategies at this time. Architectures, strategic plans, and acquisition plans for systems employing specific CAD/CAM technologies will be reviewed by OSD and by each Service to ensure that system integration guidelines and interface standards established by the CALS program are met. The MAISRC would focus on specific hardware system acquisitions which meet the MAISRC criteria for major systems outlined in DoD DoD Directive 7920.1.

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CAD/CAM TECHNOLOGY

QUESTION: Why is the Navy not following the Committee's fiscal year 1986 guidance on the NICADMM program? Explain in detail Navy near- and mid-term plans for the acquisition of CAD/CAM technology, the associated estimated acquisition and life cycle costs, and the acquisition strategy.

ANSWER: The Navy was told to apply $10M in FY86 OMN funds, from within its own budget to CAD/CAM. The Navy has identified that it is spending $6.17M in FY86 monies. As the Navy proceeds with the development of its CAD/CAM acquisition, it is likely that it will apply additional FY86 funds to CAD/CAM technology.

The Navy is entering the second phase of a three phase CAD/CAM acquisition program. The first phase was the CAEDOS contract put in place by its laboratory community. The second phase Navy Graphics CAD/CAM Acquisition (NGCA) is being put in place by NAVSEA for the Systems Commands (including the laboratory community). This phase has passed Milestone Zero, and is expected to be at Milestone II before the end of FY86. The third phase, planned for FY 93, consists of two parts. The first part is to start now with the establishment of a dedicated technical support site at David Taylor Naval Ship Research and Design Center. This site will support the NGCA acquisition, but is principally aimed at establishing a firm technical basis from which the Navy can commence its third acquisition phase in 1993.

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CAD/CAM TECHNOLOGY

QUESTION: How large are the contracts that Navy plans to let under the Navy Graphics CAD/CAM (NGCA) acquisition program?

ANSWER: This information will be known at Milestone II by the end of FY 1986.

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CAD/CAM TECHNOLOGY

QUESTION: Why is the Department not planning to require vendors to bid on the total known requirement, such as is common for standard mini- and micro-computer contracts -- some of which may cost as high as $480 million (e.g., AF AMMUS contract).

ANSWER: Vendors may bid on the total known requirement. That is why the Navy has embarked on an extensive Request for Information process. Vendors may also bid on a selected portion of the requirement. The Navy recognized that the CAD/CAM industry and its technical base is both maturing and dynamic. Further, the Navy has articulated a phased, competitive acquisition strategy leading into the late 90's. The Navy believes that a single award to one organization would neither nurture the industry nor provide a vigorous competitive environment for the Navy's third acquisition phase in 1993. This strategy was outlined by the Navy when it briefed industry representatives on 7 Feb 1986 and released its RFI to industry for comment. The overall acquisition strategy selected by the Navy will balance the requirements of [illegible] functional integration against the objective of maintaining [illegible]ition.

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CAD/CAM TECHNOLOGY

QUESTION: Has OSD formally approved the Navy's CAD/CAM acquisition strategy? If so, why are you allowing a piecemeal, fragmented approach, Dr. Wade?

ANSWER: OSD has not formally approved the Navy CAD/CAM acquisition strategy, because it would be premature for us to do so. The Navy has not fully formulated the details of their strategy. They will have done this when they complete System Decision Paper (SDP) I/II before the end of FY86. We are in frequent face-to-face communication with the Navy as their acquisition strategy is being defined. As a result of this dialogue, we consider the approach they are developing to be neither piecemeal nor fragmented. The Navy has in place a CALS Steering Board chaired by a flag officer on the CNO staff. The systems commands have each provided flag/SES membership on this board, which is monitoring the CAD/CAM acquisition. Each systems command and associated CNO staff sponsor are rigorously documenting their requirements and developing formal acquisition plans. The acquisition strategy will be structured to satisfy the interface requirements identified in a preliminary system design that integrates functional requirements and information flows for major user communities such as the SSN-21 acquisition. The proposed strategy will be reviewed by OSD prior to release. The Navy is also moving promptly to establish a CAD/CAM control site in keeping with OSD's relationship with NBS.

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CAD/CAM TECHNOLOGY

QUESTION: What funds by appropriation or industrial fund are contained in the fiscal year 1987 Navy budget for NGCA?

ANSWER: This information will not be available until System Decision Paper (SDP) I/II are completed.

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CAD/CAM TECHNOLOGY

QUESTION: Summarize the response the Navy has received to the NGCA proposal recently sent to industry.

ANSWER: Attached is the list of the organizations who have responded to the Navy's RFI. This initiative of the Navy will begin the deliberate application of computer technology to the full range of the Navy's Computer Aided Logistic Support (CALS) requirements under a set of common technical standards. This should reduce the effort which has to be devoted to establishing compatibility among competitively acquired hardware, and permit full focus on the capability of the technology to support mission accomplishment.

Adra Systems, Inc.
Analysis Technology
Apollo
Autodesk
Autotrol Technology
Baham Corporation
Boeing Computer Services
Calay
Calma
CAE International
CIMLINC
Computational Graphics
Computational Mechanics
Computervision
Conrac
Control Data Corporation
Convex Computer Corporation
Cray Research, Inc.
Daisy Systems Corp.
Digital Equipment Corporation
Electronic Data Systems Corp.
Fairline Technologies, Inc.
Filetek
Floating Point Systems, Inc.
Gerber Scientific Instrument Co.
Hewlett Packard
Holquin
Honeywell, Inc.
Intec
InterCAD Corporation
Intergraph Corporation
International Business Machines
Jonathan Corporation
Lockheed Corporation
Martin Marietta Data Systems
McDonnell Douglas Automation
Optigraphics

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PDA Engineering
Precision Image
Prime Computer
Scientific Calculations, Inc.
Silicon Compilers
Silicon Graphics
SMS Data Products Group
Sun Microsystems, Inc.
Symbolics
Synercom
Tektronix
Texas Instruments
Valid Logic Systems
Veritec Sesam Systems
Versatec
VSE Corporation

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CAD/CAM TECHNOLOGY

QUESTION: Provide for the record the fiscal year 1986 and earlier funds which Navy has obligated for CAD/CAM acquisitions. Provides programmed, committed, obligated, and expended amounts by year, appropriation/fund, and contract.

ANSWER: The Navy CAD/CAM program is not identified as a line item in the budget; and the requirement for CAD/CAM equipment is not separately programmed and budgeted. Instead, requirements are budgeted at each individual activity when needed. CAD/CAM equipments are almost exclusively NIF funded.

The CAEDOS contract was the primary vehicle through which the Naval community procurred CAD/CAM equipment in the early 80's. Expenditures made against this contract were as follows.

Year	Amount
1982	$19,263,397.55
1983	$15,194,310.29
1984	$16,308,735.96
1985	$12,822,928.54
1986	$15,203,945.90

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CAD/CAM TECHNOLOGY

QUESTION: What OSD official is responsible for and accountable for the efficient acquisition of CAD/CAM technology and its efficient integration into DoD logistics systems?

ANSWER: Because of the ambigucus nature of the term "CAD/CAM," there can be no one single person/organization responsible for the technology implied by the tenn. Instead, applications of CAD/CAM are the responsibility of the individual organization (at the appropriate level of command) where CAD/CAM technologies are used as tools. Through the Computer Aided Logistic Support (CALS) program, OSD will provide guidance on the use of interface standards to ensure compatibility and integration of the automated systems providing CAD/CAM capabilities. The Director of the OASD(A&L) Weapon Support Improvement Group, Mr. Russell R. Shorey, is Chairman of the DoD-wide CALS Steering Group, which is responsible for coordination and implementation of the CALS program.

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CAD/CAM TECHNOLOGY

QUESTION: What ADP expertise does this office possess?
ANSWER: Mr. Shorey has a background in system design and weapon system design and support planning that includes work at Lincoln Laboratory and the MITRE Corporation, responsibility for strategic and tactical command and control system projects in OUSDRE, and current responsibility for Computer Aided Logistic Support program implementation. He is supported in CALS management by a DoD staff that includes an individual with a Ph.D in operations research, another who has extensive military and civilian experience in management of weapon system acquisition programs using computer aided technologies, and another with a broad background in design and implementation of automated logistic management systems. In addition, The National Bureau of Standards (NBS) has detailed to Mr. Shorey a Senior Executive Professional Engineer with considerable experience in CAD/CAM research at NBS as well as having served at NBS as Director of Standards. The CALS program under Mr. Shorey's direction is supported by an NBS team of data system interface specialists and an OSD CALS Office that will be staffed with Military Department experts in the use of automation technology for weapon system acquisition and support.

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CAD/CAM TECHNOLOGY

QUESTION: What specific CAD/CAM expertise does it have?
ANSWER: The heavy emphasis placed on CAD/CAM capabilities as a key element in CALS implementation has insured that the personnel involved in CALS program management have a extensive knowledge of CAD/CAM systems and applications. One of the DoD personnel listed in the preceding paragraph is a member of both the national IGES Steering Committee and the American National Standards Institute Committee involved in developing and publishing standards for CAD/CAM interfacing. The NBS CALS support team includes technical specialists with considerable direct expertise in CAD/CAM technology.

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FORM 2136

NEWS RELEASE
OFFICE OF ASSISTANT SECRETARY OF DEFEN
(PUBLIC AFFAIRS)
WASHINGTON, D.C. 20301
PLEASE NOTE DATE

HOLD FOR RELEASE
UNTIL 9:00 A.M. (EDT)
WEDNESDAY, SEPTEMBER 3, 1986

No. 428-86
695-3886 (Info.)
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REMARKS PREPARED FOR DELIVERY BY
THE HONORABLE WILLIAM H. TAFT, IV
DEPUTY SECRETARY OF DEFENSE
AT THE FEDERAL COMPUTER CONFERENCE
CONVENTION CENTER, WASHINGTON, D.C.
WEDNESDAY, SEPTEMBER 3, 1986

IT IS A PLEASURE TO BE HERE THIS MORNING TO ADDRESS THE FEDERAL COMPUTER CONFERENCE.

IN A COMPLEX WORLD AS INSTANTANEOUSLY DANGEROUS AS IT IS TODAY, WHERE THE DEMANDS FOR KNOWLEDGE ARE GREAT, WE APPEAR TO BE IN A RACE BETWEEN THE DEMAND FOR INFORMATION AND THE ABILITY OF OUR INFORMATION AND COMMAND AND CONTROL SYSTEMS TO PROVIDE, PROCESS, AND USE IT.

THIS CONFERENCE WILL SERVE MOST IMPORTANTLY IF IT PROMOTES A BETTER UNDERSTANDING OF THIS VERY DELICATELY BALANCED PROBLEM--INFORMATION DEMAND AND SYSTEMS CAPABILITIES TO PROVIDE AND USE IT.

CLEARLY, COMPUTER TECHNOLOGY HAS HAD A PROFOUND IMPACT ON THE DEFENSE DEPARTMENT AND OUR DEMANDS FOR CERTAINTY. THE IMPORTANCE OF THE COMPUTER TO THE TECHNOLOGIES THAT ENABLE DEVELOPMENT OF HIGH CAPABILITY WEAPONS SYSTEMS CANNOT BE OVERESTIMATED. PERHAPS NOT AS VISIBLE AS WEAPON SYSTEMS, BUT JUST AS VITAL IN THE LARGE AND COMPLEX TASK OF DEFENDING THE NATION, IS THE MANAGEMENT AND LOGISTICS SIDE OF DEFENSE--AND COMPUTER TECHNOLOGY HAS AN IMPORTANT ROLE HERE, TOO. THE 1986 FEDERAL COMPUTER CONFERENCE, WITH ITS THEME, "LEVERAGING ADP RESOURCES," RECOGNIZES THE POTENTIAL OF TECHNOLOGY IN ENHANCING THE EFFICIENCY AND EFFECTIVENESS OF THE MILITARY, AND ALL OF GOVERNMENT, AND OUR RESPONSIBILITY FOR MAKING IT HAPPEN. THERE ARE TWO ELEMENTS TO THE CHALLENGE: FIRST, TO CONTINUE TO APPLY THE LATEST TECHNOLOGY IN NEW WAYS TO MAKE GOVERNMENT MORE EFFECTIVE; AND SECOND, TO MANAGE THE GOVERNMENT'S ADP RESOURCES TO GET THE MOST FROM THEM, WHILE ALSO ELIMINATING WASTE AND MINIMIZING INEFFICIENCY.

THIS MORNING I WOULD LIKE TO DISCUSS SOME OF THOSE AREAS THAT OFFER GREAT POTENTIAL FOR GAINING MANAGEMENT EFFICIENCIES THROUGH APPLICATIONS OF ADP AND COMMUNICATIONS TECHNOLOGY, AND LEAVE YOU WITH A FEW THOUGHTS ON WHAT DoD NEEDS FROM THE COMPUTER HARDWARE AND SOFTWARE INDUSTRIES.

OUR INTEREST IN COMPUTERS IS NOT NEW. SINCE THE 1950's, DoD HAS HAD A VITAL INTEREST IN COMPUTER TECHNOLOGY DEVELOPMENT FOR SEVERAL APPLICATIONS:

MORE

- SCIENTIFIC APPLICATIONS, WHERE THE INTENSIVE COMPUTATIONAL NEEDS OF WEAPON SYSTEM DESIGN HAVE SERVED BOTH AS A DRIVER OF, AND A MAJOR MARKET FOR, SCIENTIFIC COMPUTERS.

- WEAPON SYSTEM APPLICATIONS, WHERE EMBEDDED COMPUTERS ARE PART OF VIRTUALLY EVERY NEW WEAPON SYSTEM. THESE EMBEDDED COMPUTERS GIVE US A CLEAR, QUALITATIVE EDGE OVER POTENTIAL ADVERSARIES.

- COMMAND, CONTROL, COMMUNICATIONS AND INTELLIGENCE (C^3I) APPLICATIONS. MODERN DIGITAL COMMUNICATIONS ARE THE CENTRAL NERVOUS SYSTEM OF OUR MILITARY CAPABILITIES.

- GENERAL PURPOSE ADP APPLICATIONS, WHERE WE USE COMPUTERS IN DoD FOR THE SAME RANGE OF BUSINESS, INDUSTRIAL AND OTHER APPLICATIONS THAT THE PRIVATE SECTOR DOES. BUT IN DoD, WE DO IT ON A LARGER SCALE AND WITHIN A COMPLICATED FRAMEWORK OF LEGISLATIVE CONSTRAINTS AND FEDERAL PROCUREMENT REGULATIONS.

TIME DOES NOT PERMIT ME TO GO INTO OUR PROGRAMS IN THE SCIENTIFIC AND EMBEDDED SYSTEM APPLICATION AREAS. SUFFICE IT TO SAY THAT DoD IS CONTINUING ITS ROLE OF NATIONAL LEADERSHIP WITH ITS SPONSORSHIP OF SUCH PROGRAMS AS:

- DARPA's STRATEGIC COMPUTING PROGRAM, AND THE PARALLEL PROCESSING TECHNOLOGY IT HAS PRODUCED FOR THE NEXT GENERATION OF SUPERCOMPUTERS, AND

- DEVELOPMENT OF ADA AS THE COMMON LANGUAGE FOR THE EMBEDDED SYSTEMS OF THE 1990's.

THE MANAGEMENT IMPROVEMENTS WE SEEK WILL COME LARGELY IN THE AREAS OF COMMUNICATIONS AND GENERAL PURPOSE ADP. IN THE 1960's AND 70's, DoD, LIKE THE PRIVATE SECTOR, INVESTED IN NUMEROUS STAND-ALONE ADP SYSTEMS.

- WE AUTOMATED PAYROLL AND ACCOUNTING, PERSONNEL, INVENTORY MANAGEMENT, MAINTENANCE RECORDS, MESSAGE AND TRANSACTION PROCESSING AND SO FORTH.

- WHAT RESULTED WERE "ISLANDS OF AUTOMATION", EACH WITH UNIQUE HARDWARE AND SOFTWARE. THEY COULD NOT COMMUNICATE WITH EACH OTHER AND WERE EXTREMELY DIFFICULT AND EXPENSIVE TO UPDATE.

TODAY, INDUSTRY IS UPDATING AND INTEGRATING ITS ISLANDS OF AUTOMATION WITH TREMENDOUS PAYOFFS.

- FOR EXAMPLE: A NATIONAL ACADEMY OF SCIENCES STUDY IN 1984 FOUND THAT COMPANIES WHICH HAD INTEGRATED THEIR COMPUTER-AIDED DESIGN AND MANUFACTURING (CAD/CAM) SYSTEMS, HAD REDUCED ENGINEERING DESIGN COSTS BY 15-30 PERCENT AND HAD INCREASED PRODUCTIVITY DRAMATICALLY.

DoD MUST ACHIEVE SIMILAR BENEFITS, BOTH IN TERMS OF ECONOMIC PAYOFFS AND IN INCREASED MILITARY EFFECTIVENESS.

THREE AREAS THAT APPEAR TO HAVE HIGH PAYOFF ARE BEING PURSUED:

- CONTINUED EMPHASIS ON MODERNIZING OUR GENERAL PURPOSE COMPUTER BASE

- UPGRADING OUR DEFENSE COMMUNICATIONS SYSTEMS, AND

- AUTOMATING THE INTERCHANGE OF TECHNICAL INFORMATION WITHIN DoD AND BETWEEN DoD INDUSTRY

THE FUNDAMENTAL FUNCTIONAL DESIGNS OF MANY OF OUR ADP SYSTEMS ARE OLD AND REQUIRE MAJOR RELESIGN. AS A RESULT, A MAJOR MODERNIZATION EFFORT IS IN PROCESS.

- THIS CONSTITUTES AN IMPORTANT PART OF OUR FY 1986 BUDGET OF $7.5B TO DESIGN, PROCURE AND OPERATE GENERAL PURPOSE ADP SYSTEMS.

- SPECIFICALLY, THE SERVICES HAVE MORE THAN 40 MAJOR COMPUTER SYSTEMS ACQUISITION PROGRAMS UNDERWAY WITH A TOTAL COST OF APPROXIMATELY $20B OVER THEIR SYSTEMS LIFE.

THIS MAJOR RESOURCE COMMITMENT WILL REQUIRE SEVERAL MANAGEMENT ACTIONS:

- STRONG MANAGEMENT PLANNING AND OVERSIGHT DURING EACH STEP OF THE DEVELOPMENT CYCLE.

- PENETRATING ASSESSMENT OF OUR ALTERNATIVES TO INSURE THAT THE SELECTED APPROACH WILL BE SUCCESSFUL.

- CONTINUED EMPHASIS ON SETTING GOALS AND EXPECTATIONS COMMENSURATE WITH WHAT WE CAN DELIVER AND AFFORD.

HOWEVER, IN DOING THIS WE MUST NOT BECOME SO INVOLVED IN HIGH TECHNOLOGY OPPORTUNITIES THAT WE LOSE SIGHT OF THE BUSINESS OR MISSION PROBLEM THAT WE ARE TRYING TO SOLVE.

BUT THE CENTRAL QUESTION IS HOW BEST TO USE THESE NEW SYSTEMS IN AN INTEGRATED WAY TO COPE WITH THE "RACE" I MENTIONED EARLIER: OUR EVER GROWING DEMAND FOR INFORMATION, ON THE ONE HAND, AND THE VOLUMES OF INFORMATION THESE NEW SYSTEMS ARE PROVIDING US. THE SPARES PROCUREMENT BUSINESS PROVIDES A GOOD EXAMPLE OF THE PROBLEMS WE FACE.

- DoD IS SPENDING APPROXIMATELY $22 BILLION ANNUALLY TO PROCURE SPARES;

- WE EXECUTE SOME 15 MILLION PROCUREMENT TRANSACTIONS A YEAR;

- WE HAVE 1000 DoD BUYING OFFICES DEAL WITH 300,000 VENDORS.

ANOTHER QUESTION--IN FACT A PAINFUL "LESSON LEARNED"--IS THE PROBLEM OF SOFTWARE MANAGEMENT. THE AIR FORCE'S "OPERATION BOLD STROKE", WHICH DEALS WITH THIS IMPORTANT PROBLEM, IS AN AMBITIOUS PROJECT TO IMPROVE SOFTWARE MANAGEMENT BY EDUCATING PEOPLE THROUGHOUT THE SERVICE ABOUT SOFTWARE AND MAKING THEM AWARE OF ITS CRITICAL IMPORTANCE TO A GROWING NUMBER OF PROGRAMS. PROJECT BOLD STROKE HAS ALREADY WON ACCLAIM WITHIN DoD, AND COULD WELL BECOME A MODEL FOR THE OTHER MILITARY SERVICES AND CIVILIAN AGENCIES TO FOLLOW. I NOTICE THAT THERE IS A CONFERENCE AGENDA ITEM ON THE TRENDS THAT PROMPTED THE AIR FORCE TO INITIATE PROJECT BOLD STROKE, ALONG WITH ITS OBJECTIVES AND THE PLANS FOR ITS IMPLEMENTATION.

MORE

VIRTUALLY ALL THE MAJOR ELEMENTS OF DoD's WORLDWIDE DEFENSE COMMUNICATIONS SYSTEM ARE UNDERGOING DRAMATIC CHANGES TO TAKE ADVANTAGE OF INTEGRATED ADP AND COMMUNICATIONS TECHNOLOGIES.

WE HAVE AN OBVIOUS NEED TO PROTECT THE SENSITIVE DATA PROCESSED BY OUR ADP AND COMMUNICATIONS SYSTEMS. "INFORMATION SECURITY" IS EMERGING AS A TECHNOLOGY THAT IS VITAL TO OUR NATIONAL INTERESTS. WE NEED LOW COST ENCRYPTION AND AUTHENTICATION DEVICES, SECURE NETWORK COMMUNICATION FEATURES AND "TRUSTED" COMPUTER HARDWARE AND SOFTWARE.

DoD FACES A MAJOR TECHNICAL CHALLENGE IN BRINGING ALL THESE NEW DEVELOPMENTS TOGETHER INTO AN INTEGRATED TOTAL SYSTEM. INDUSTRY FACES A SIMILAR CHALLENGE, AND WE HOPE TO GET MAXIMUM LEVERAGE ON OUR PROBLEMS BY APPLYING THE STANDARDS, PROTOCOLS, ARCHITECTURAL SCHEMES, AND OTHER TOOLS DEVELOPED BY THE PRIVATE SECTOR. IN AREAS WHERE DoD SYSTEMS NEED TO COMMUNICATE WITH INDUSTRY'S SYSTEMS, WE ARE COMMITTED TO USING NATIONAL AND INTERNATIONAL STANDARDS WHEREVER POSSIBLE.

TO GAIN THE EFFICIENCIES AND ECONOMIC PAYOFFS WE SEEK, DoD WILL INDEED NEED TO COMMUNICATE WITH INDUSTRY'S DATA SYSTEMS. A PRIME TARGET FOR DIGITAL DATA EXCHANGE IS THE LARGE VOLUME OF TECHNICAL DATA REQUIRED TO SUPPORT A WEAPON SYSTEM THROUGHOUT ITS LIFE CYCLE. CONSIDER:

- DoD SPENDS AN ESTIMATED $5B ANNUALLY TO ACQUIRE AND MAINTAIN WEAPON SYSTEM TECHNICAL DATA. THIS INCLUDES MILLIONS OF PAGES OF TECHNICAL MANUALS, ENGINEERING DRAWINGS AND OTHER INFORMATION ESSENTIAL TO WEAPON SYSTEM OPERATION, MAINTENANCE AND PROCUREMENT OF SPARE PARTS.

- WITH THE UNAVOIDABLE INCREASING COMPLEXITY OF WEAPON SYSTEMS AND THEIR LOGISTIC SUPPORT, WE ARE IN DANGER OF DROWNING IN PAPER.

  -- 200 MILLION ENGINEERING DRAWINGS STORED IN 38 DoD REPOSITORIES NATIONWIDE.

  -- 750,000 PAGES IN THE TECHNICAL MANUAL FOR THE NEW B-1B BOMBER.

  -- 200,000 TECHNICAL MANUALS IN THE NAVY'S INVENTORY REQUIRE FIVE MILLION CHANGE PAGES ANNUALLY.

WE NEED A FUNDAMENTAL CHANGE IN THE WAY WE DO BUSINESS. LAST SEPTEMBER, ACTING ON THE RECOMMENDATION OF A DoD-INDUSTRY TASK FORCE, I SIGNED A POLICY MEMORANDUM ON COMPUTER AIDED LOGISTIC SUPPORT (CALS). THE CALS INITIATIVE COMMITS DoD TO TRANSITION FROM OUR CURRENT PAPER-INTENSIVE LOGISTIC PROCESSES TO A HIGHLY AUTOMATED AND INTEGRATED MODE OF OPERATION BY THE EARLY 1990's.

THREE HIGH PAYOFF AREAS ARE TARGETED FOR IMPROVEMENT:

- INTEGRATING RELIABILITY AND MAINTAINABILITY DESIGN TOOLS INTO THE COMPUTER AIDED DESIGN (CAD) SYSTEMS INDUSTRY USES TO DESIGN OUR WEAPONS. THE PAYOFF WILL BE MORE RELIABLE, SUPPORTABLE WEAPON SYSTEMS WITH REDUCED LIFE CYCLE COST AND GREATER COMBAT CAPABILITY.

MORE

- AUTOMATING THE PROCESSES USED BY CONTRACTORS TO GENERATE TECHNICAL INFORMATION. THE PAYOFF HERE IS MORE ACCURATE AND TIMELY AND LESS EXPENSIVE TECHNICAL DATA PRODUCTS.

- RAPIDLY INCREASING DoD CAPABILITY TO RECEIVE, DISTRIBUTE AND USE TECHNICAL INFORMATION IN DIGITAL FORM. THE PAYOFF HERE WILL BE A GREAT REDUCTION IN PAPER, WITH CONCOMMITANT REDUCTIONS IN COSTS, IMPROVEMENTS IN TIMELINESS AND ACCURACY, AND DELIVERY TO THE USER IN A MORE USABLE FORM.

IN THE EARLY 1990's, WE WILL BUY ACCESS TO CONTRACTOR DATA SYSTEMS INSTEAD OF HUGE STACKS OF PAPER. WE WILL STORE ENGINEERING DRAWINGS ON OPTICAL DISKS, AND OFFER DIGITAL DATA PACKAGES FOR SPARES PROCUREMENT. WE WILL PROVIDE MAINTENANCE PERSONNEL WITH INTERACTIVE MAINTENANCE AIDS INSTEAD OF VOLUMINOUS MANUALS. WE WILL AUTOMATE ROUTINE PROCUREMENT ACTIONS WITH OUR SUPPLIERS. A START HAS ALREADY BEEN MADE IN ALL OF THESE AREAS:

- MAJOR SUPPLIERS HAVE PROVIDED TERMINALS FOR OUR BUYERS TO ACCESS THEIR DATA BASES OF PARTS INFORMATION.

- AUTOMATION OF ENGINEERING DRAWING REPOSITORIES IS UNDERWAY IN ALL THREE SERVICES AND THE DEFENSE LOGISTICS AGENCY.

- PROTOTYPE "PAPERLESS" TECHNICAL MANUAL SYSTEMS ARE BEING TESTED.

- DoD IS ACTIVELY PARTICIPATING WITH INDUSTRY GROUPS IN DEVELOPING PROTOCOLS FOR ELECTRONIC BUSINESS DATA INTERCHANGE.

DESPITE THE ENCOURAGING INITIAL PROGRESS, WE FACE A NUMBER OF CHALLENGING PROBLEMS IN IMPLEMENTING CALS:

- STANDARDS ARE NEEDED TO EXCHANGE DATA IN DIGITAL FORM. THE PRESENT INDUSTRY PROCESS FOR DEVELOPING, VALIDATING AND IMPLEMENTING STANDARDS IS VOLUNTARY AND SLOW. DoD NEEDS TO ACCELERATE THE PROCESS FOR CALS, AND HAS OBTAINED THE SUPPORT OF THE NATIONAL BUREAU OF STANDARDS FOR THIS ENDEAVOR.

- THE SEPARATE MILITARY DEPARTMENTS AND AGENCIES NEED TO PRESENT A UNIFIED FACE TO INDUSTRY. A NEW DoD CALS POLICY OFFICE HAS BEEN ESTABLISHED TO PERFORM A COORDINATING ROLE.

- AGREEMENT BETWEEN DoD AND INDUSTRY IS NEEDED ON THE FUNCTIONAL REQUIREMENTS TO BE INCLUDED IN FUTURE WEAPON SYSTEM CONTRACTS, AND ON THE DEVELOPMENT OF COMPATIBLE DoD AND INDUSTRY ARCHITECTURES FOR EXCHANGING DIGITAL DATA.

WE NEED TO ESTABLISH AND NURTURE CLOSE COOPERATION BETWEEN DoD, THE DEFENSE INDUSTRY, AND THE COMPUTER HARDWARE AND SOFTWARE SUPPLIERS TO MOUNT AN EFFECTIVE ATTACK ON THESE PROBLEMS.

- WE MUST RECOGNIZE THAT DoD AND INDUSTRY VIEW THE ISSUES FROM DIFFERENT PERSPECTIVES.

MORE

- WE MUST FIND WAYS TO ACHIEVE TRUE INTEROPERABILITY WHILE PRESERVING PROPRIETARY RIGHTS TO HARDWARE AND SOFTWARE.

- WE MUST COOPERATE IN THE ESTABLISHMENT OF STANDARDS AND SPECIFICATIONS TO OUR MUTUAL ADVANTAGE.

AMONG THE ALTERNATIVES PROPOSED FOR DEVELOPMENT OF COMPATIBLE DoD AND INDUSTRY ARCHITECTURES, THE IDEA OF AN INDUSTRY-FUNDED CONSORTIUM OFFERS THE ADVANTAGE OF LETTING THE INDUSTRY EXPERTS CLOSEST TO THE PROBLEM COME UP WITH SOLUTIONS WITH A MINIMUM OF OUTSIDE DIRECTION. I WOULD ENCOURAGE INDUSTRY TO GET TOGETHER ON SUCH AN APPROACH. I WILL ENSURE DoD PROVIDES THE INTERFACES TO MAKE SUCH AN APPROACH EFFECTIVE.

I AM PLEASED TO SEE THAT THE SPECIAL DoD TRACK IN YOUR CONFERENCE AGENDA IS DEVOTED TO THE CALS INITIATIVE. THE FIRST YEAR'S PROGRESS WILL BE REPORTED THERE.

WHAT DOES DoD NEED FROM THE COMPUTER HARDWARE AND SOFTWARE INDUSTRY? IN A WORD: INTEROPERABILITY.

- YOU WILL SEE IN FUTURE DoD PROCUREMENTS THAT WE WILL INSIST ON INTEROPERABILITY OF THE SYSTEMS WE USE DoD-WIDE. WE WILL ADOPT COMMON SYSTEMS WHERE COMMONALITY MAKES SENSE, BUT AN ENTERPRISE AS LARGE AS DoD WILL ALWAYS BE FACED WITH A MIX OF DISSIMILAR EQUIPMENT AND SOFTWARE. WE NEED INTEROPERABILITY BOTH ON A FUNCTIONAL LEVEL, WHERE SYSTEMS MUST COMPLEMENT ONE ANOTHER IN THE EXCHANGE OF INFORMATION, AND ON A TECHNICAL LEVEL, SO WE CAN REPLACE OR UPGRADE OUR SYSTEMS OR COMPONENTS WITHOUT BEING LOCKED IN TO A SINGLE SUPPLIER.

- FURTHERMORE, WE NEED SOFTWARE THAT IS TRULY TRANSPORTABLE FROM ONE SYSTEM TO ANOTHER, AND EASILY MAINTAINED.

- OUR NEEDS FOR INTEROPERABILITY ARE NOT UNIQUE. THE NEED FOR SO CALLED "OPEN SYSTEM ARCHITECTURES" IS BEING RECOGNIZED BY HARDWARE AND SOFTWARE SUPPLIERS AND HAS BECOME A POWERFUL MARKET FORCE. THIS PERCEPTION IS AS CORRECT FOR DoD AS IT IS FOR THE PRIVATE SECTOR MARKET.

IN SUMARY, DoD IS COMMITTED TO ACHIEVING THE PAYOFFS PROMISED BY ADP MODERNIZATION, UPGRADING OUR COMMUNICATIONS SYSTEMS, AND CALS. EVIDENCE OF OUR COMMITMENT IS THAT WE HAVE PRESERVED THE FUNDING FOR PRODUCTIVITY ENHANCING INVESTMENTS IN ADP AND IN INTEGRATION PROGRAMS LIKE CALS, EVEN IN THE FACE OF SEVERE BUDGET CONSTRAINTS. WE EXPECT AN EQUALLY SERIOUS COMMITMENT FROM COMPUTER HARDWARE AND SOFTWARE SUPPLIERS TO PROVIDE SYSTEMS THAT WILL BE INTEROPERABLE AND WILL ACHIEVE THE ANTICIPATED PAYOFFS. YOUR EFFORTS CAN BE INSTRUMENTAL IN HELPING US TO DO SO. AND WHY IS THIS SO IMPORTANT? BECAUSE IT WILL MAKE BETTER USE OF CRITICAL DEFENSE AND RARE RESOURCES IN THE YEARS AHEAD--AND THAT MEANS MORE DEFENSE CAPABILITY.

THANK YOU VERY MUCH.

END